

**SEPTEMBER 1952**

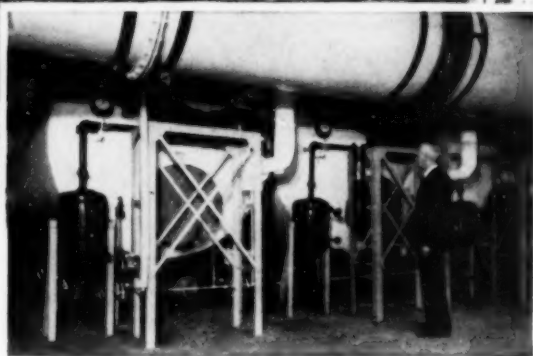
# **Chemical Engineering Progress**

**PUBLISHED MONTHLY BY THE AMERICAN INSTITUTE OF CHEMICAL ENGINEERS**

# 95% of Gasoline Solvent Recovered

with **COLUMBIA** Activated Carbon

Trade-Mark



## WRITE FOR BOOKLET

Send for our 16-page booklet "How 7 Industries Save \$150,000,000 a year with COLUMBIA Activated Carbon" which tells how other companies have profited. A request on your letterhead will bring you a copy, without obligation. Write today.

## CARBIDE AND CARBON CHEMICALS COMPANY

A Division of  
Union Carbide and Carbon Corporation  
30 East 42nd Street **UCC** New York 17, N. Y.



**COLUMBIA**

*Activated  
Carbon*

A modern solvent recovery plant for The Garlock Packing Company, Palmyra, New York, using COLUMBIA Activated Carbon as the adsorbent, collects about 1,000 pounds of gasoline vapor per hour from the air and delivers it ready for re-use. The gasoline is vaporized during the manufacture of asbestos sheet packing and is recovered at lower cost and higher efficiency than is possible with any other commercial method. Operating records for a 10-month period since the plant started show an *overall* recovery efficiency of 95.9 per cent. In addition to the profitable recovery of gasoline, this installation also:

- improves the working conditions in the plant.
- helps reduce the hazards of handling gasoline vapors,
- avoids the discharge of large volumes of solvent-laden air into the atmosphere.

The special features of CARBIDE's automatic equipment and the high adsorptive capacity of COLUMBIA Activated Carbon make such performance possible for Garlock Packing.

If you vaporize solvents in your process, let CARBIDE help you conserve valuable solvents, improve processing conditions, and clean up exhaust air. We can supply you with a complete, automatic, instrument-controlled plant designed for your specific requirements with guaranteed operating efficiency to recover solvent vapors or purify industrial gases.

"Columbia" is a registered trade-mark of Union Carbide and Carbon Corporation

Volume 48

Number 9

# Chemical Engineering Progress

SEPTEMBER

1952

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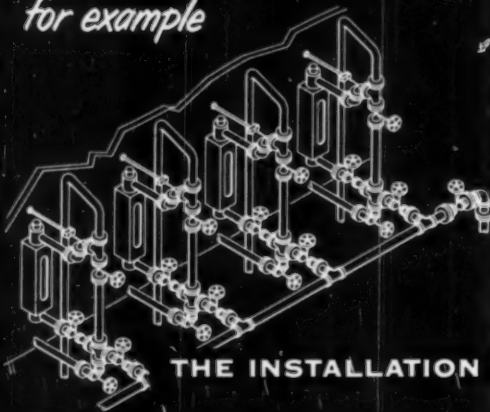
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# Are You Getting Value Like This from Your Valves?

...on Bleach Plant Piping  
for example



THE INSTALLATION

Crane valves on chlorine rotameter control board in pulp stock bleach plant of The Northwest Paper Co., Cloquet, Minn.

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Tough and destructive as is chlorine service on valves, this plant is enjoying greater freedom from valve trouble than ever before. Since installing Crane Chlorine Valves, more than 4 years ago, the plant finds them "the best we have ever used."

Operating at pressures from 70 to 100 psi, at 110 degrees F., these Crane valves have required but minimum maintenance and servicing. They have helped make important savings in chlorine valve costs. The customer reports 3-way satisfaction with Crane Chlorine Valves: their good performance; their low cost of maintenance; and their continual ease of operation.

The Complete Crane Line Meets All Valve Needs. That's Why  
More Crane Valves Are Used Than Any Other Make!

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Branches and Wholesalers Serving All Industrial Areas

VALVES • FITTINGS • PIPE • PLUMBING • HEATING

## VALVE SERVICE RATINGS

### CORROSION-RESISTANCE:

*Excellent*

### SUITABILITY:

*Designed for chlorine service*

### MAINTENANCE COST:

*Low - Routine only*

### SERVICE LIFE:

*Now more than 4 years*

### OPERATING RESULTS:

*Better, safer chlorine control*

### PRICE:

*Lowest cost  
in terms of service given*

### AVAILABILITY:

*Stock item in Crane line*

## THE VALVE

Strong yet compact, Crane No. 1644 Forged Steel Valves are recommended for chlorine gas or liquid, free from water, at temperatures up to 300 deg. F. Disc and seat ring are Hastelloy "C"; stem is Monel. Hard deposits do not hinder this narrow-bearing, tight-seating design. Bonnet joint remains leakproof with corrugated soft Monel gasket. Globe and angle patterns. See your Crane Catalog or Crane Representative.



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- Temperatures as high as 212°F. do not affect the resin.
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- This high exchange capacity is obtained with a minimum of swelling.
- Special applications for AMBERLITE IR-45 include the adsorption of acids from organic reaction mixtures, isolation and concentration of pharmaceuticals, exchange of anions in slightly acidic media, and recovery of metals.
- For water conditioning, AMBERLITE IR-45 is recommended for use with cation exchangers of all types, particularly in Monobed systems.

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CHEMICALS

FOR INDUSTRY

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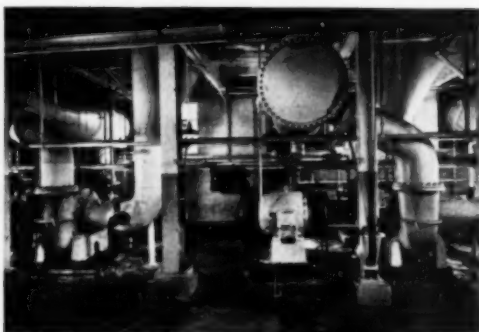
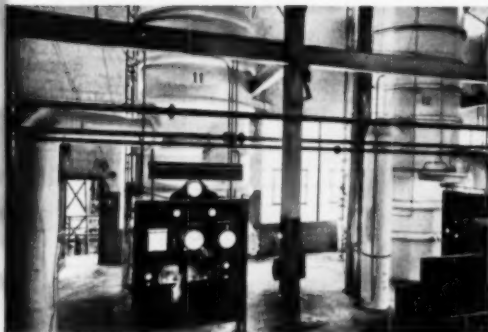
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to do  
your job  
best!*

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Dewaterers, Dryers,  
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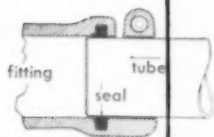
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**stainless steel fitting**  
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**without threading or welding**

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 Bulletin Q100



Designed to reduce assembly costs and to permit the use of less expensive lighter wall tubing. **Quikupl** stainless steel elbows, tees, couplings, reducers and adapters save you time, labor, materials and money.

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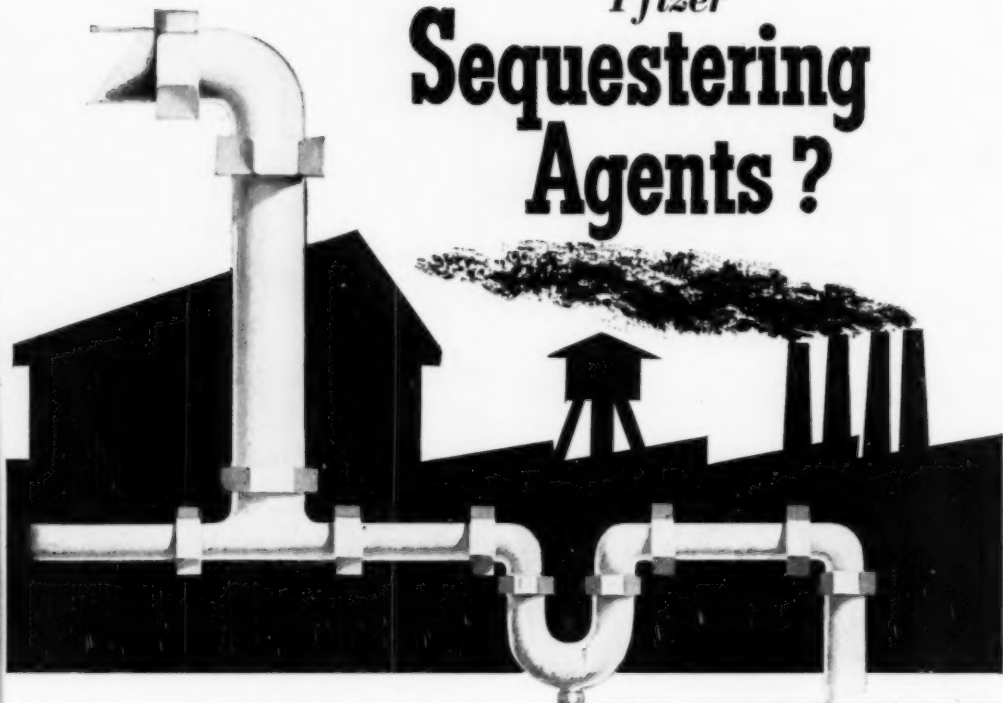
**Quikupl** means safe, leakproof connections! Synthetic sealing rings provide positive pressure-tight joints at all times.

**Quikupl** means simplified fitting inventories! Use it with schedules 5, 10, 40 and 80 pipe sizes without changing from one fitting to another . . . use it with a variety of tube wall thicknesses as long as the O.D. remains the same.



LEADING PRODUCER OF STAINLESS STEEL VALVES, FITTINGS & CASTINGS

Do You Know  
the "Ins and Outs" of these  
*Pfizer*  
**Sequestering  
Agents ?**



• Unwanted traces of iron, aluminum, copper and other metals picked up from pipe lines and processing equipment can be rendered inactive by the use of a Pfizer sequestering agent. You can put "in" Pfizer Citric or Gluconic Acid—or one of their derivatives\*—to sequester "out" the metallic contaminants which interfere with efficient operation in your plant.

Pfizer Citrates and Gluconates are recommended as sequestering agents in...

**The textile industry**...to inactivate trace metals in dyeing, bleaching, kier boiling and mercerizing.

**The leather industry**...to adjust tanning solutions to the proper pH without precipitation.

**Oil and fat industry**...to inactivate trace metals which lead to rancidity.

**Weed killer formulations**...to prevent formation of insoluble, inactive salts in hard water areas.

**Municipal and industrial water systems**...to prevent the precipitation of metallic contaminants.

\*Sodium Citrate, Sodium Gluconate,  
Ammonium Gluconate

PUT "IN"	SEQUESTER "OUT"	pH
<b>CITRIC ACID</b> <small>Sequestering action of 100 parts of acid</small>	Iron (Ferric)	19 Parts 7
	Aluminum	19 Parts 7
	Copper	26 Parts 7
	Zinc	44 Parts 7
	Cobalt	95 Parts 10
<b>GLUCONIC ACID</b> <small>Sequestering action of 100 parts of acid</small>	Iron (Ferric)	24 Parts 7
	Aluminum	4 Parts 7
	Copper	26 Parts 7
	Zinc	27 Parts 7
	Cobalt	8 Parts 10



Pfizer has a wealth of information on the effectiveness of these Citrate and Gluconate sequestering agents. For additional data, write:

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# Girdler Process News



## GIRDLER DESIGNS AND BUILDS New plastics materials plant for B. F. Goodrich Chemical Co. in record time!

**H**ERE is the fourth major chemical project completed by Girdler for B. F. Goodrich Chemical Company... a plant now producing large quantities of Geon® polyvinyl materials.

Based on Girdler's past performance, B. F. Goodrich Chemical assigned Girdler a "package" contract for process engineering and construction. The plant was completed economically and in record time to meet the increased demand

for Geon materials for consumer and defense use.<sup>1</sup>

For process plants in the chemical, natural gas, and petroleum industries, Girdler assumes unit responsibility for design, process engineering, and construction. Such coordination centralizes responsibility, and saves time.

To assure successful results, call on Girdler in the *planning stages* of your processing facilities.

<sup>1</sup>HYGIRTOL is a trade mark of The Girdler Corp.

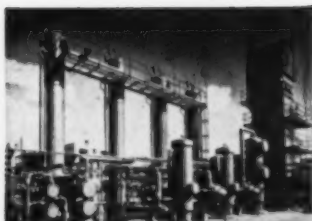
## The **GIRDLER** Corporation

LOUISVILLE 1, KENTUCKY  
Gas Processes Division

**GAS PROCESSES DIVISION:** *Designers, Engineers, and Constructors for the Petroleum and Chemical Industries*

**VOTATOR DIVISION:** *Processing Apparatus for the Food and Chemical Industries*

**THERMEX DIVISION:** *Industrial High Frequency Dielectric Heating Apparatus*



**Hydrogen Plant.** This plant, the second Girdler HYGIRTOL® unit purchased by Lever Brothers Company, assures a dependable source of high-purity hydrogen for hydrogenation of vegetable oils at Lever's new Los Angeles plant. Instruments control the process, and only one man is required to keep the plant in operation, furnishing hydrogen at any desired rate. Purity generally exceeds 99.8%, and operation is safe, quiet, and clean.



**Synthesis Gas Plant.** Girdler has broad experience in handling complete "process packages", covering design and construction of process plants involving very high operating pressures, high temperature reactions, and corrosive substances. This synthesis gas plant is a unit of a complete synthetic nitrogen fertilizer plant which operates with a lower unit energy input than any similar plant in existence.

### Want More Information?

Girdler's Gas Processes Division designs and builds plants for the production, purification, or utilization of chemical process gases; purification of liquid or gaseous hydrocarbons; manufacture of organic compounds. Write for Booklet G-35, The Girdler Corporation, Gas Processes Division, Louisville 1, Kentucky. District Offices: New York, Tulsa, San Francisco. In Canada: Girdler Corporation of Canada Limited, Toronto.



# THE BIG LINE OF VACUUM PUMPS

**COMPOUND PUMPS**

Model	Free air displacement
Model CVM 3153	2 cu. ft. per min.
Model CVM 3534	5 cu. ft. per min.
Model CVM 556	15 cu. ft. per min.
Model CVM 8610	46 cu. ft. per min.

**SINGLE STAGE PUMPS**

Model	Free air displacement
Model VSM 556	13 cu. ft. per min.
Model VSD 778	27 cu. ft. per min.
Model VSD 8811	47 cu. ft. per min.
Model DVD 8810	110 cu. ft. per min.
Model DVM 12814	218 cu. ft. per min.
Model DVD 14918	311 cu. ft. per min.
Model DVD 141418	486 cu. ft. per min.
Model DVD 181420	702 cu. ft. per min.
Model DVD 272034	1600 cu. ft. per min.

**Kinney**  
VACUUM PUMPS

There's a Kinney Pump for every vacuum requirement. Write for Bulletin V-518. Kinney Manufacturing Co., 1546 Washington St., Boston 30, Mass. Representatives in New York, Chicago, Cleveland, Philadelphia, Houston, New Orleans, Los Angeles, San Francisco, Seattle. FOREIGN REPRESENTATIVES: Gen'l Engineering Co., Ltd., Rodcliffe, Lancs., England. • Horrocks, Roxburgh Pty., Ltd., Melbourne, C. I. Australia. • W. S. Thomas & Taylor Pty., Ltd., Johannesburg, South Africa. • Novalectric, Ltd., Zurich, Switzerland. • C.I.R.E., Piazza Cavour 25, Rome, Italy.

since 1919...

# DEVOE

WONDER-1-COAT  
HOUSE PAINT



*Nothing takes the place  
of Glycerine*

The Jones-Dabney Division of Devoe and Reynolds Company began using Glycerine to produce alkyd resins over 30 years ago. Today, the same Glycerine-derived alkyds which are used for every industrial coating application from bobbypins to battleships—can also be found in the famous Devoe line of enamels and interior finishes.

## FULLY ACCEPTED... FULLY AVAILABLE IN ALL GRADES!

First, it was industrial finishes... now, in one of the most outstanding recent developments in the industry, Glycerine-derived alkyd resins have been introduced to the entire household interior coating field!

Pioneers in this new application of alkyd resins is America's oldest paint maker: Devoe and Reynolds Co. Inc. For years Devoe has recognized in Glycerine a vital chemical intermediate in the manufacture of its alkyd resins and ester gums. With these Glycerine-derived alkyds, Devoe marine and industrial coatings have earned a world-wide reputation for gloss, brightness and resilience.

Like Devoe, America's leading paint makers have found Glycerine easier to work with in the critical resin-making operation. For light-colored alkyds, Glycerine is available to meet the exacting standards of the color-conscious paint industry.

"Why Glycerine for Alkyd Resins and Ester Gums?" tells the story of these applications with detailed information on the chemical and physical properties of Glycerine. Write for your copy.

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295 Madison Avenue, New York 17, N. Y.

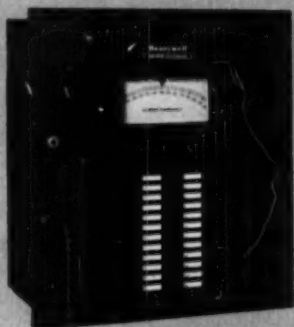
# Applications Unlimited...

*wherever you need to measure,  
... choose*

## *ElectroniK Potentiometers*

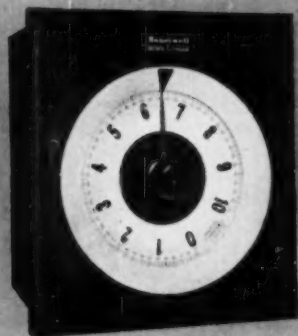
WHETHER charting the course of an experiment on a laboratory bench, or regulating huge-scale production in a sprawling processing plant, *ElectroniK* Potentiometers point the way to accelerated research, to greater productivity, to higher quality, and to lower costs.

Versatile *ElectroniK* Instruments are supplied calibrated for variables such as pressure, temperature, level, flow, pH, conductivity, speed and motion. A wide selection of instruments provides a choice of indicators, single and multi-point recorders, and a variety of electric and pneumatic



### PRECISION INDICATOR

centralizes up to 48 different readings on one instrument; just press a button and wide-open scale turns quickly to measured value.



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set point and measured values are easily read on 2½-foot circular scale. Supplied for on-off and proportional electrical control.



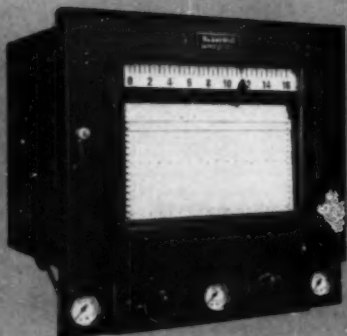
● *Important Reference Data...*

## *record or control*

controllers from the simplest to the most complex types. In all these, the *ElectroniK* "continuous balance" measuring system, with electronic non-cyclic balancing, affords the peak of speed, sensitivity and service-proved dependability.

Plan now to gain the full benefits of automatic instrumentation throughout your plant. Call in your local Honeywell engineer . . . he is as near as your phone.

MINNEAPOLIS-HONEYWELL REGULATOR CO.,  
Industrial Division, 4427 Wayne Avenue, Philadelphia 44, Penna.



**Of special interest  
to research men...**

### **FUNCTION PLOTTER**

automatically charts temperature vs. expansion, speed vs. torque, stress vs. strain. One variable actuates the pen, the other actuates the chart drive.

### **DUPLEX RECORDER**

simultaneously records any two independent variables. Two pens actuated by separate measuring systems can both travel full width of the chart.

### **ELECTROMETER**

records currents as small as  $10^{-16}$  amperes, for measurements with ionization chambers, spectroscopes, etc.; features fast response, low noise, high stability.

### **Recorders**

Circular chart type with  $28\frac{3}{4}^\circ$  scale can be read at a distance. Strip chart type records as many as 16 points. Scanners available for larger number of points. Pen speeds as fast as one second.

### **Electric Controllers**

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### **Pneumatic Controllers**

Choice includes on-off control, Limited Throttler and Full Throttler controllers with manual reset, Air-O-Line Controller with automatic reset. Rate action is optional.

MINNEAPOLIS  
**Honeywell**  
BROWN INSTRUMENTS

*First in Controls*

For a brief description of all Honeywell Instruments, write for Composite Catalog 5000.

**HERE'S HOW TO HANDLE**

**BRINE PURIFICATION**

with a  
**Dorrco Clariflocculator\***

Installed at a Southwestern chemical plant, this 125' dia. Dorrc Clariflocculator precipitates and removes calcium and magnesium compounds from more than 2,000 gpm of salt brine. Clariflocculator effluent goes directly to electrolytic chlorine cells.

The Clariflocculator is a natural for any brine purification job. Its design provides for flocculation and clarification in separate compartments — yet, unlike many combination units, it takes magnesium compounds in its stride. Fluctuations in feed volume and density are no problem either.



**WE'LL BE GLAD TO TELL YOU MORE** about the Clariflocculator — or discuss the techniques of brine purification with you at your convenience. The Dorr Company, Barry Place, Stamford, Conn.

\*Reg. U. S. Pat. Off.



*Better tools TODAY to meet tomorrow's demand*

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**WORLD - WIDE RESEARCH • ENGINEERING • EQUIPMENT**

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**THANKS...you told  
us to add this to  
our ads**



Here's a problem. The equipment has small cracks at (a). Will repairs be costly, long-winded jobs? Not if it's HAVEG.

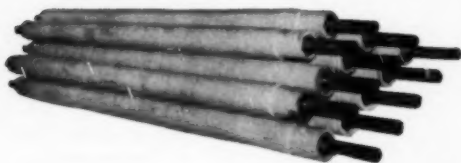
Repair HAVEG in the field. Chip out "V" grooves following clear instructions. Equipment does not have to be removed from foundation.

Cement is applied quickly after mixing. In some cases after initial set, heating may speed hardening. As soon as cement is completely hard equipment can be used.

## HAVEG CAN BE EASILY REPAIRED

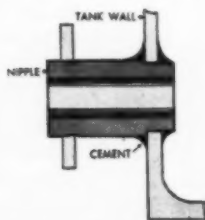
Yes, HAVEG is a superior corrosion-resistant material that can be molded into towers, tanks, pipes and valves. It's a long story and we often omit what you like best about HAVEG... that if it is damaged in transit or service HAVEG can be repaired on the spot by your workers. HAVEG cements come in comparable grades to the equipment installed; a special catalyst causes the cement to set uniformly. After hardening, the repaired section is practically as strong as the original, with good resistance to corrosion. Repair jobs on HAVEG are fast, economical, involving a minimum of lost time. Advice, help and emergency supplies of HAVEG cement are available from your nearest district office.

## HAVEG CAN BE MACHINED AND RESURFACED



Steel, textile, printing industries have found rolls surfaced with HAVEG ideally suited for applications requiring *economical* resistance to corrosion. At the Marshallton plant metal shafts are covered with HAVEG and machined to the desired diameter. After months or years of outstanding service, the roll can be returned to HAVEG for resurfacing at a considerable cost saving. Consult your HAVEG sales engineer.

## IN THE FIELD HAVEG CAN BE ALTERED



HAVEG is a versatile material, produced to help you cut costs... resist corrosion. A 64 page technical bulletin F-6 gives complete chemical resistant charts, engineering specifications, photos of completed projects. If corrosion is your problem this HAVEG manual may contain the answer... it has for thousands of chemical engineers. Write now, or call your HAVEG sales engineer.



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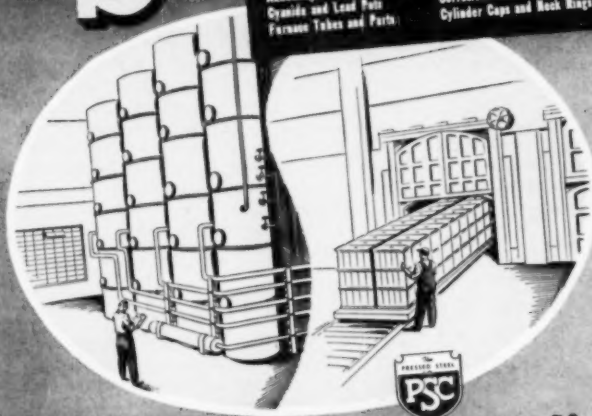
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- Baskets, cyanide dipping
- Baskets, pickling
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- Boxes, annealing & carburizing
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- Caps, cylinder (compressed gas)
- Covers, annealing (Bell furnace)
- Covers, annealing (elevator furnace)
- Fixtures, carburizing
- Flights, conveyor (syn. rubber plant)
- Headers, air pre-heating
- Manifolds, gas exhaust
- Muffles, carburizing
- Piping, process (alloy only)
- Pots, carburizing & annealing
- Pots: lead, cyanide & salt
- Racks, annealing & carburizing
- Racks, sheet pickling
- Retorts, carburizing
- Rings, neck (compressed gas cylinder)
- Tanks, copper annealing
- Tanks, pickling
- Trays, annealing & brazing
- Tubes, annealing
- Tubes, furnace vent
- Tubes, radiant furnace
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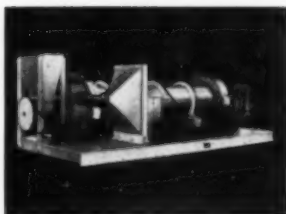
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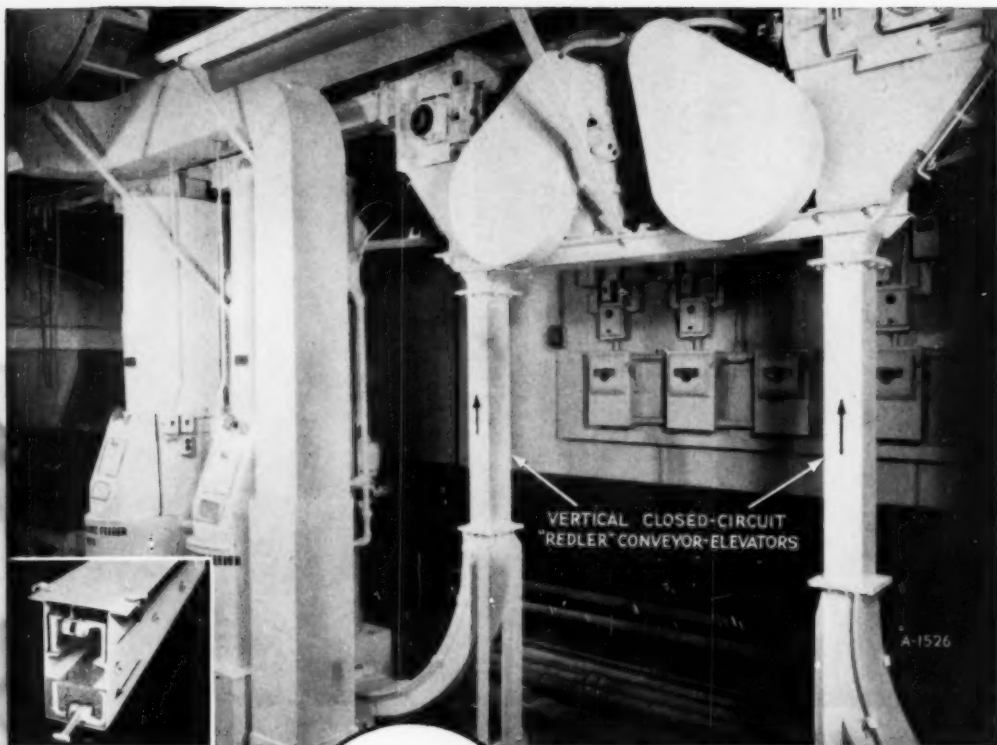
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A sanitary, dust-tight system of five REDLER vertical-closed-circuit conveyor-elevators is used to handle alum, lime, etc., from hopper boxes to storage and then to feeder units which send materials to water processing operations. Totally enclosed REDLER casings eliminate dust, prevent contamination and spillage and permit a neat, dust-free installation in a minimum of space.

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for **SANITARY, DUST-TIGHT**  
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In this modern filtration plant, an S-A System of five REDLER conveyor-elevators is employed to handle up to 20,000 pounds of chemicals per hour! . . . In minimum space! . . . At lowest cost per ton! Installations such as this are not unusual to S-A engineers—they have the experience and the equipment to solve even the most complex bulk materials handling problems efficiently and economically. A line or two on your letterhead will bring particulars promptly.

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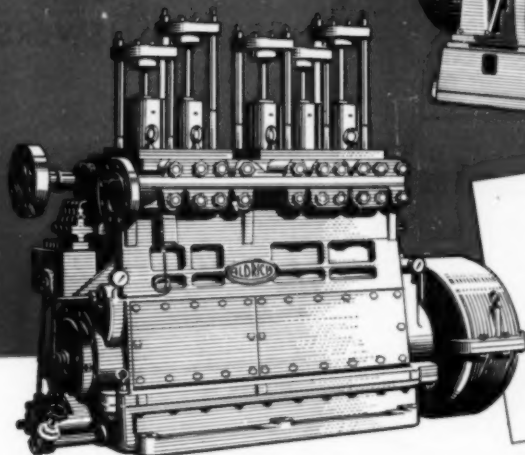
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# High Viscosity-High Pressure

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### APPLICATIONS

Among many liquids handled by Aldrich Pumps are: caustic solutions, fatty acids, nitric acid, acetic acid, aqua ammonia, anhydrous ammonia, as well as liquids encountered in the petroleum refining, petro-chemical, and other industries.

*Aldrich Direct Flow  
Triplex and  
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From our service files we can frequently make specific recommendations to meet your chemical pumping needs . . . whether they involve corrosion, high viscosity or high pressure.

Many of your requirements can be met by an Aldrich Direct Flow Pump . . . a unit featuring advantages such as: high volumetric efficiency; sectionalized fluid-end; interchangeable wearing parts (among 3-, 5-, 7-, and 9-plunger pumps);

changeable plunger sizes, and higher operating speeds which result in more work from a smaller, more compact pump.

Aldrich Direct Flow Pumps are made in 3", 5" and 6" stroke sizes. They range up to 900 hp, 7500 psi. To regulate capacity, units can be furnished with an Aldrich automatic by-pass valve control system which operates with all types of accumulators. Write for Data Sheet 64 Series.

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### **SUPER CENTRIFUGE**

(General Purpose Clarifier)

Highest centrifugal force commercially available (13,200 x g) makes this centrifuge extremely efficient for the clarification of liquids containing solids. Quick easy removal of solids from the tubular bowl, makes this unit ideal for clarification.

1



### **DD-2 CENTRIFUGE**

(High Capacity Clarifier)

Disc bowl design provides stratification of liquids at a centrifugal force of 9500 x g to effect efficient clarification. Solids remain in bowl, so generally the DD-2 is used where a relatively low percentage of solids exists in a large amount of liquid.

2



### **DH-2 NOZJECTOR**

(Continuous solids discharge clarifier)

The solids discharge continuously from a series of nozzles located around the periphery of the disc bowl. The clarified product is discharged separately from the solids with a relatively small amount of the liquid. The DH-2 is indicated where the dryness of the solids is relatively unimportant. This clarifier is often used as a valuable solids concentrator.

3

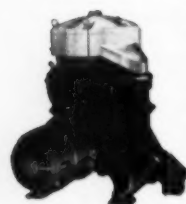


### **DG-2 AUTOJECTOR**

(Automatic continuous solids discharge clarifier)

A series of valves located around the periphery of the bowl are caused to open and close intermittently by the accumulation of solids in the bowl. The relatively dry solids discharge automatically from the valves; the clarified liquid discharges separately.

4



### **DV-2 CLARIFIER**

(Externally controlled continuous solids discharge)

A series of valves located around the periphery of the bowl are caused to open or close by an externally controlled hydraulic system. Since both duration and frequency of valve opening can be controlled closely, it is possible to discharge solids with a high degree of concentration. The DV-2 handles a wide range of slurries with high percentage of solids, and solids ranging from firm to slimy.

5

# a clarifying problem?

HERE ARE

**FIVE**

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**ONE BEST CLARIFIER  
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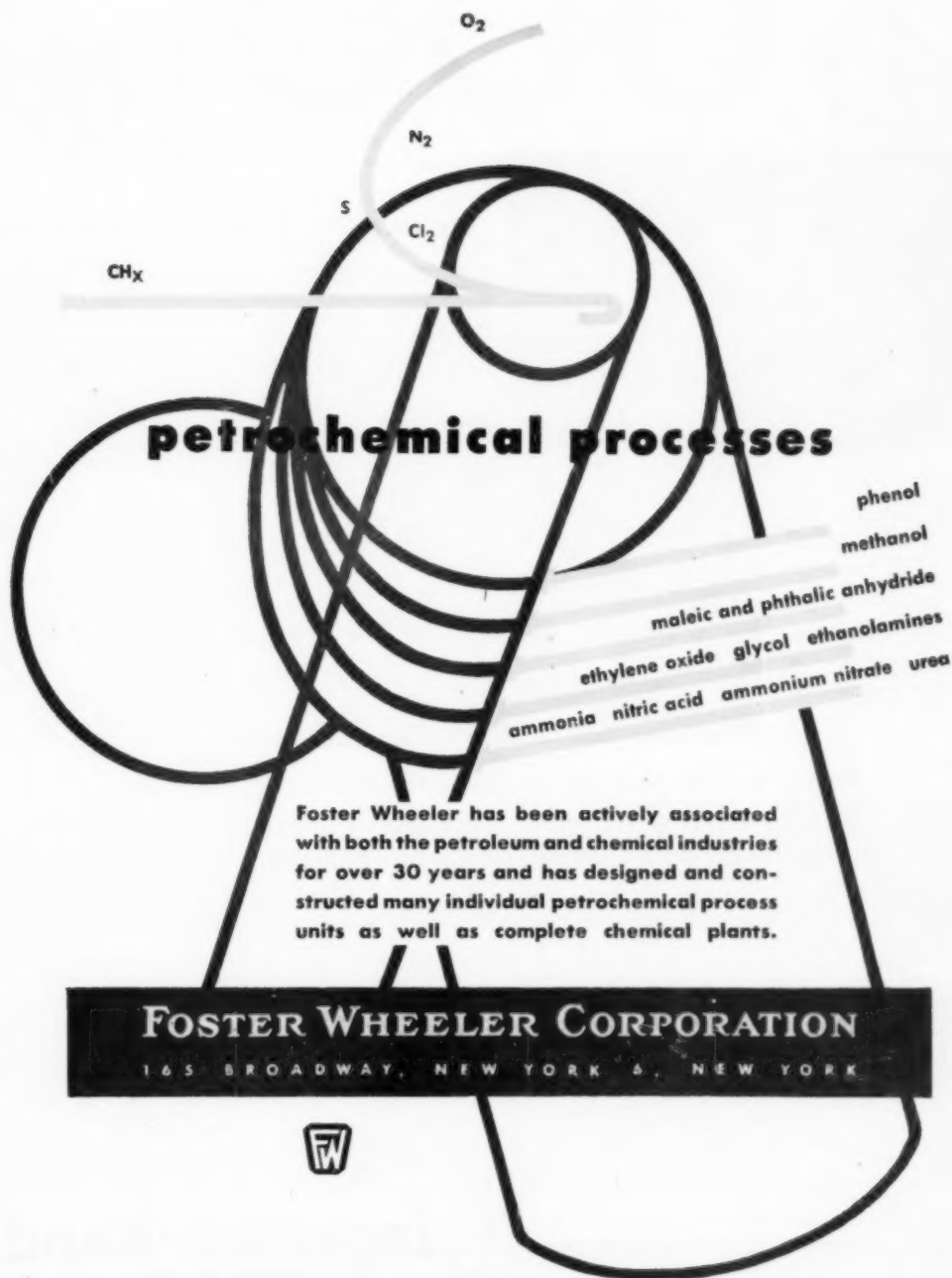
If your process involves clarification of liquids, it will pay you to get in touch with Sharples. Peak clarifying efficiency results from the choice of the one best clarifier for your particular need.

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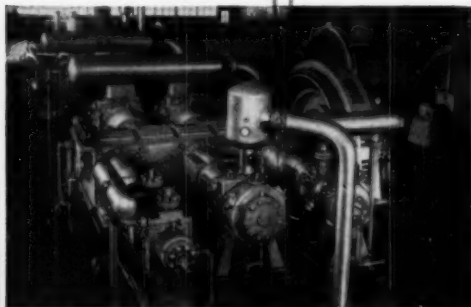


# Nitrogen and Hydrogen Compressed to

# 15,000 psi

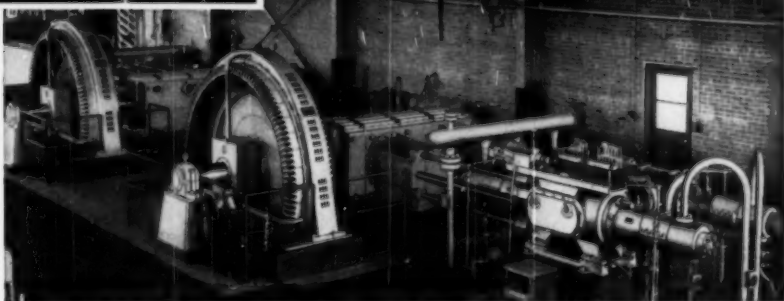
pressure

*for making Synthetic Ammonia*



Two 4-stage HHE primary compressors discharge hydrogen-nitrogen mixture at 3500 psi. Each is driven by a 2250-hp synchronous motor.

Further compression to 15,000 psi is accomplished by the two 900-hp boosters at right. These are two-stage HHE units.



## Ingersoll-Rand solves another high-pressure problem...with new HHE compressor installation at Mississippi Chemical Corporation

● When nitrogen and hydrogen are brought together under the proper condition of pressure and heat in the presence of a catalyst, the reaction yields ammonia. In the synthetic ammonia plant of the Mississippi Chemical Corporation, at Yazoo City, Miss., these two gases are mated at 15,000-psi pressure . . . with the aid of the four Ingersoll-Rand HHE compressors shown above. The plant's output is used largely as fertilizer, although synthetic ammonia is also an important chemical used to make high explosives.

This installation has two trains of compression, each consisting of a four-stage primary compressor and a two-stage booster unit. The primary unit compresses the nitrogen-hydrogen mixture from 9 psi to 3500 psi, dis-

charging to the intake of the booster unit which completes the compression to 15,000 psi.

The application of high-pressure compressors like these has been one of Ingersoll-Rand's major contributions to process industries. For various synthetic-ammonia processes alone I-R has built successful high-pressure compressors totalling more than 170,000 horsepower. Eight of them were for 15,000 psi; the remainder for pressures from 3,000 to 5,000 psi. The first units are still in operation after 27 years of service at 4500 psi.

If you have a process-compressor problem, your I-R representative is well qualified to give you expert assistance, no matter what the gas, pressure, or process.

COMPRESSORS • AIR TOOLS • ROCK DRILLS • TURBO BLOWERS  
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Technical data on the revolutionary new

# holo-flite\*

(HOLLOW-FLIGHT)

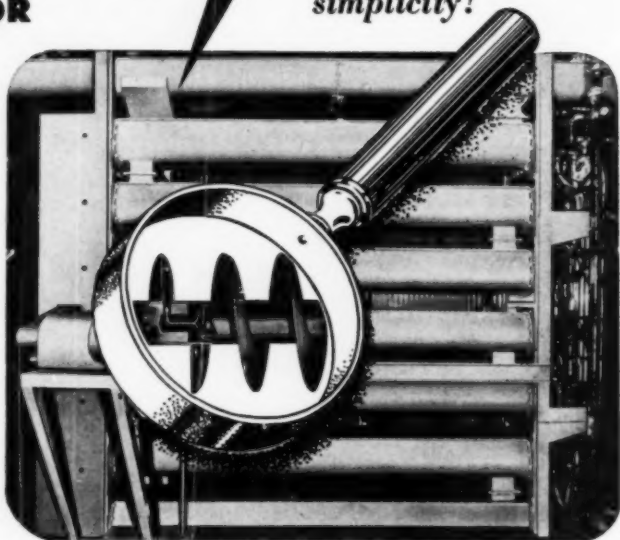
## PROCESSOR

If you have processing operations where slurries, solids, pulps or pastes must be cooled or cooked, be sure to investigate the many unique advantages of the newly-developed HOLO-FLITE Processor before you install any heat-exchange equipment.

### Here's the HOLO-FLITE principle...

Two or more screw conveyors rotate slowly in a trough. The blades and shaft of each flight of conveyors are hollow, with provision for circulating the heat-transfer agent through them. The product to be cooled or cooked is moved along the trough, being constantly rotated into, around, over and under the conveyor screws as it moves.

Thus, a continuous thermal transfer takes place between the product and the heat-transfer fluid circulating in the blades. The product is cooled or cooked in continuous-flow without the "stop-and-go" losses of batching operations... and cooled products can be packaged directly from the HOLO-FLITE discharge—saving space, time and additional handling.



THIS 6-TIER HOLO-FLITE cools 7 tons of cottonseed press cake per hour from 285° to 89°F. in a total floor space of only 28 sq. ft.  
(Inset) Enlarged cutaway view of HOLO-FLITE screw showing heat-transfer principle.

### Here are typical HOLO-FLITE advantages

The HOLO-FLITE principle is so unique it is setting completely new standards of performance in many ways. For example...

\*Reg. T.M.

#### The HOLO-FLITE Saves Space

—It requires as little as 1/5th the space of other units of comparable capacity because (1) it has far greater heat-transfer area per cubic foot of space... and (2) the flights can be "tiered" as high as desired to give maximum capacity in very small floor areas.

**The HOLO-FLITE is Versatile**—Processed product can be fluid, pulp or paste—granular, crys-

talline or powdered solid. Heat-transfer fluid can be refrigerant, cooled or ambient water, steam, oil or any other desired fluid, at any normal temperature range.

#### The HOLO-FLITE is Dust-Free

—Its gentle action provides large heat-transfer action without dust and with negligible particle abrasion. Simplifies installations, assures higher quality product.

#### The HOLO-FLITE is Adaptable

—It can easily be designed to handle virtually any capacity by (a) varying the diameter of the screws (7" to 16")... (b) varying the length of the screws (8 ft. to 20 ft.)... (c) varying the number of intermeshing screws per trough (2, 4, or 6)... and (d) varying the number of tiers stacked on top of one another (1 to 10, or more).

The HOLO-FLITE is in daily operation on such typical products as sand, cement, cottonseed cake, soybean meal, borax, salt, sugar, baby foods and many other equally-varied products.

**What is your problem?** Our engineers will be glad to assist you in making the most of HOLO-FLITE advantages. Write wire, or phone the office nearest you!

**Want More Facts?** This 8 page booklet describing the HOLO-FLITE in greater detail will gladly be sent on request. No obligation, of course.



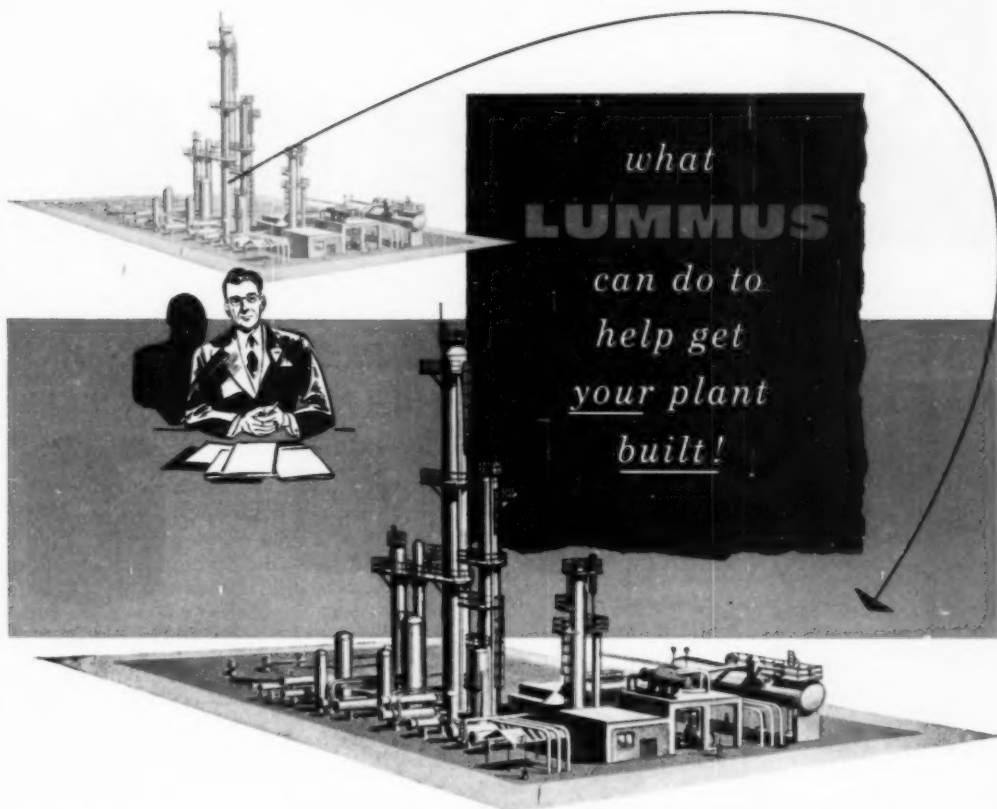
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Design, engineer and construct it? Of course. These three main classes of service—performed under *one* contract with *single* responsibility—are our bread and butter. They have produced more than 600 plants of all types in just about every country where petroleum is refined or chemicals are made.

Today's conditions, however, call for departures from "routine." Otherwise, endless complexities, shortages, etc., could require three times the normal effort to get a plant built. But Lummus has the quality and versatility of staff—the breadth and depth of opera-

tions, to meet these conditions head-on and help you maintain near-normal status.

It could work like this. In the interest of "first things first," you may need basic studies and reports covering alternative routes for reaching your goal. If so, rely on Lummus to develop analyses on which to base sound capital investment decisions.

Perhaps your problem is not so much with process units themselves, but with tying the whole system together for full operating efficiency. Lummus has long-established expe-

rience in laying out and installing complete off-site facilities—the bringing in of utilities—piping to introduce charge materials and carry off products—tankage, dockage, loading facilities, etc. This is "know-how" you can use to advantage.

Among other added factors are the considerable help we afford in procuring materials, and invaluable counsel in interpreting government rules and regulations—all in all, unique services geared to the times.

We invite you to use our various services, either singly or in combination—to get that plant *built!*

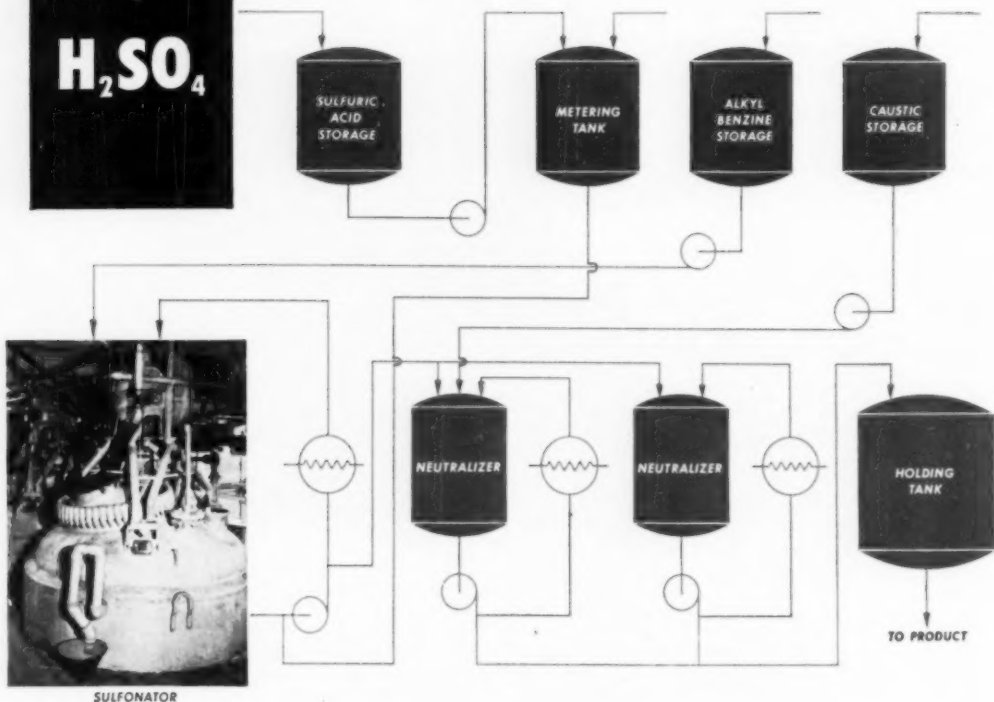


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For across-the-board resistance to corrosion by sulfuric acid, glassed steel is *the only completely suitable material of construction* available today. Glassed steel is fully resistant to dilute solutions up to the boiling point and to concentrated solutions at temperatures up to 450°F. It is equally inert in the critical range of 60-96% concentration of  $\text{H}_2\text{SO}_4$ . It is not attacked by fuming sulfuric acid (oleum) and its corrosion resistance is not affected by aeration, velocity, impurities, or the use of mixed acid. No inhibitor is ever required.

For these reasons, glassed steel equipment has virtually unlimited service life in processes using sulfuric acid. Further, it eliminates the possibility of contamination or undesired catalysis which may be caused by the presence of even small traces of metal in solution.

Pfaudler glassed steel is resistant to *all* acids except hydrofluoric, even at elevated temperatures and pressures. With a new Pfaudler glass, it is possible to handle not only acids but also *alkaline solutions* up to a pH of 12

and 212°F. It is now possible to perform both acid reactions and neutralizations in a single glassed steel vessel.

To give it working strength, Pfaudler glass is fused to steel in huge furnaces at temperatures of 1500-1700°F. *This high-temperature firing locks the glass to the steel and makes it hard and tough.*

Pfaudler glassed steel pressure reactors, in capacities from 5 to 3500 gallons, are commonplace in chemical processing today. These units are equipped with agitation, are usually jacketed, and are supplemented by a complete line of standard glassed steel accessories. Custom-built vessels as large as 8300 gallons, for severe chemical service, have been constructed. Glassed steel columns and evaporators solve many serious corrosion problems.

Whenever you have an equipment problem requiring *corrosion resistance, durability, and versatility*, as well as the *economy* which these features provide, look to Pfaudler glassed steel for the solution. Write for Bulletin 894-S2, our new general catalog.

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# OPINION AND COMMENT

## DEFERMENTS—HOW TO HELP

**T**HE need for intelligent action with Selective Service in obtaining deferment of essential employees continues. The necessity for such action will be with us for many years to come, apparently, and industry and the Selective Service organization should, if possible, find the smoothest operating principles for themselves in presenting data for deferment procedures.

Industry owes it to itself to try to defer as many chemical engineers as it can and, of course, Selective Service owes it to the nation to make certain that all men qualified and in essential positions, are deferred in order that a constant flow of armament and materials shall not be stopped.

Much of the hysteria about deferment has passed. The seekers of evil portent, the shrillers of danger, and the publicity seekers have left the scene, and now it is up to industry and Selective Service to work out calmly and competently, the best procedures for deferment and intelligent action. A step in this direction was recently taken by national headquarters of the Selective Service system in setting up an outline which will help in the job evaluation of an industry worker. General Hershey assigned the scientific advisory committee to develop a special outline to study cases referred to the committee by the director. General Hershey had a Presidential Appeal Board express to him dissatisfaction with the way employers were describing employees' jobs and job level verifications.

For the benefit of those faced with deferment procedures in industry, we are pleased to print below "Outline for an Occupational Investigation" which the Scientific Advisory Committee is now using.

1. Training and educational history of registrant. Where did he stand in class (if information is available)?
2. Employment experience prior to job with present employer.
3. Nature of previous job assignments with present employer.

4. Employment assignments on present job.
5. Size, nature, and function of group registrant is assigned to as worker.
6. Registrant's function in the group.
7. Product on which registrant is working and end use.
8. Relation of product to national health, safety, and interest.
9. Relation of product to defense or mobilization.
10. Range of salaries on this job and average salary of comparable employees. Salary of registrant.
11. Period of training customary for the job.
12. Frequency with which nonprofessional personnel are hired in similar category.
13. If registrant is on training program, how long has he been on it?
14. How long does the training program last?
15. What is registrant's effectiveness in relation to his fellows?
16. What success and/or difficulties has the employer encountered in recruiting for registrant's type of job?
17. What are the shortages or overages in this category of employment—in registrant's plant? Nationally?
18. If classified previously in II-A, how long has he been so classified?
19. To what extent has the employer already lost employees to the Armed Services in the category of the registrant?

The governmental organizations and committees feel that if in the past such information originally had been supplied on draft cases to the local board, classification of trained scientific personnel, particularly with reference to II A, would have been enormously simplified and speeded.

As for the future, it is believed that while experts will be needed to determine the importance of some specialists, if all the above information is originally supplied to the Selective Service Board, great strides will have been taken in increasing the number of successful job deferments requested by industry.

S. L. TYLER

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Installed cost .....\$32,000  
Drying time.....300 minutes  
Drying cost.....\$1.42 per 100 lb.  
(space required, 2,000 sq. ft.)

### LOUISVILLE DRYER

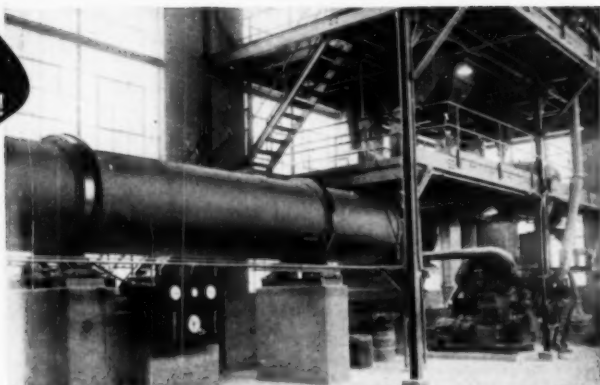
Installed cost .....\$78,000  
Drying time.....25 minutes  
Drying cost.....\$0.415 per 100 lb.  
(space required, 900 sq. ft.)

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### LOUISVILLE DRYER

### IN OPERATING COSTS

**ALONE... \$40,000**



Sometimes the cheapest drying methods are the most expensive!

Take the case of this producer of synthetic resin for plastics. His situation was studied by a Louisville engineer who uncovered this fact: by investing *more* money in a Louisville Dryer—especially designed for the job—savings would more than write off the cost of the new equipment in less than 2 years. In addition, total enclosure of the material to be dried would mean no contamination from airborne dust, dirt. Speeded-up drying time improved product quality.

Tests in our own research laboratories and pilot plant predetermined the performance of this custom-built dryer. Have a Louisville engineer survey your drying methods. No obligation. Write today.

Ask for new treatise on subject of rotary dryers  
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### Louisville Drying Machinery Unit

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# SELLING

## Its Importance in the Chemical Industry

There are great marketing opportunities for chemical engineers in sales. . . . What is required in the sales functioning of a chemical engineer if he is to be successful? . . . Here is a story—in four articles—of a salesman in the chemical field. . . . Selling is not merely a matter of an extrovert personality and a generous expense account. . . . It requires true, knowledgeable facts of the industry and of your own product and of the customers' needs. . . . For those who want to consider this field, *Chemical Engineering Progress* starts here a series of articles on sales opportunities in the chemical field.



J. W. Kinsman

J. Warren Kinsman, vice-president of E. I. du Pont de Nemours & Co., Wilmington, Del., attended Wesleyan University and was first employed by the Du Pont Co. in 1915 as a timekeeper. After several years' experience in manufacturing, he entered upon sales activities and has also served in executive capacities for a number of his company's operations. He became general manager of one of Du Pont's industrial departments in 1944; a member of its board of directors in 1946; and a vice-president and a member of its executive committee in 1947. His interest in research and product development led to a variety of projects including the establishment of three technical sales service laboratories. Currently he is a director of the National Sales Executives, Inc., and of the National Association of Manufacturers, being also chairman of its public relations advisory committee.

**T**HE time is now propitious to bring into focus the importance of the selling function in our economy, especially under conditions which are likely to confront us in the years immediately ahead.

Many men, especially young men, who have embarked on chemical-engineering careers may have been so engrossed in research, plant construction, process development, and manufacturing operations that they have had little time to acquaint themselves with one of the cardinal props of our enterprise system and economy—the selling function—or to consider their dependence upon it for success in their own fields of endeavor. In view of existing world conditions it may well be that selling is the one major effort in our national life which is destined, more than any other, to *save us from an economic collapse*.

Our country has been living, especially in recent years, under an aura of excessive demand for the derivatives of its natural resources and its manufacturing skills and efficiency—in part because of its generosity to the people of other nations, torn by the ravages of wars or victimized by political exploitations.

The time may well come—and soon too—when those give-away markets and the enormous expenditures for defense against aggressors will largely disappear, when the productive capacities of countries in Europe, Asia and South

America have been restored, or even built beyond their own needs.

When that situation comes about, it is almost inevitable that our own enormous capacity to produce goods will be in excess of our established domestic needs. We shall then be challenged with the serious problems of creating new markets, of developing new and better methods of distribution, and of intensifying our selling to keep our factories busy, to avoid unemployment, to support our research, and still to earn a return for the millions of investors who have risked their savings in our industrial enterprises.

### What Is Selling?

Selling is an art which, unlike a scientific principle, cannot be reduced to a precise formula. Rather, it is an unending effort to cope with new problems and to avoid repeating errors and mistakes which are inevitably made as part of the price of building up experience and judgment.

Selling and salesmanship are important because they are the dynamic forces which make the wheels go 'round and keep sound and vital the economy of our country. Nothing moves or happens—at least not much—until sales and repeat sales are made continually so that laboratories and factories can be built; men and women can be employed and kept employed; and the products of their efforts can be distributed and utilized by others for conversion or consumption to employ others or to satisfy the needs of others.

But of equal importance with sales are finance, research and manufacturing. Each is indispensable to the other.

### The Part Finance Plays

A manufacturing enterprise can be thought of as a tripod. The base upon which it stands is *finance*. It represents the savings of thrifty people, who spend less than they make in order to save something to invest as venture capital to earn for them a greater income than is possible solely from their manual or intellectual efforts. Finance is responsible for the administration of their monetary interest in the business.

On this triangular base, by the functioning of our enterprise system, three stalwart supports are erected to form a structure that is sound against toppling unless erosion or decay occurs in any of the supporting columns of this geometric structure which engineering teachings tell us is fundamentally stable.

**The first of these tent poles or props is research.**

For many years the word research has meant diligent investigation, searching,

experimenting and planning. It was and still is the precursor, the forerunner of what one is to do.

So, after investment financing in consideration of the profit motive incentive has been provided, we start investigations, searching, planning, researching—if that is the preferable word—toward new or improved products, plant design and construction, equipment installation and manufacturing operations and simultaneously plan our sales policies, programs and campaigns for the new venture.

**Thus the second supporting tent pole or prop to be erected is manufacturing and, of course, the third is sales.**

With the erection of the third prop the structure is completed and, in time, if all goes well, it becomes solidified into a sturdy tetrahedron. Assuming financing has been prudent and adequate, we are now ready to compete for a share of the consumers' dollar, but it is certain that we will laboriously and painstakingly have to work our way up through the long line of people who are striving to get that same dollar.

In their intenseness toward the solution of scientific problems, many chemists and engineers may not have realized that the sole and ultimate objective of engaging in business, in research, or in manufacturing is to make a profit by supplying human needs and, in the process, to build a better and more complete way of life.

### Basic Needs of Humanity

There are eight basic wants of humanity: food and drink, shelter and creature comfort, freedom from fear and danger, desire to progress and be superior, desire to attract the opposite sex, welfare of loved ones, enjoyment of social approval and desire to live longer.

The chemical industry plays an important role towards fulfilling all eight. Should anyone doubt that the industry is engaged in promoting desire to attract the opposite sex, he need only be reminded that chemistry is the foundation of the synthetic fiber business, the perfume and cosmetics industries, and the dye stuffs industry with its peacock colors—to mention only a few. It is no exaggeration to say that women have played an inspirational role in the attainment of many scientific achievements.

The United States Department of Commerce recognizes some 78 branches of endeavor—major segments of our country's business, commerce and industry. Every one of them is today and probably forever will be dependent upon the chemical industry. In that fact rests a great opportunity and also an equally great responsibility.



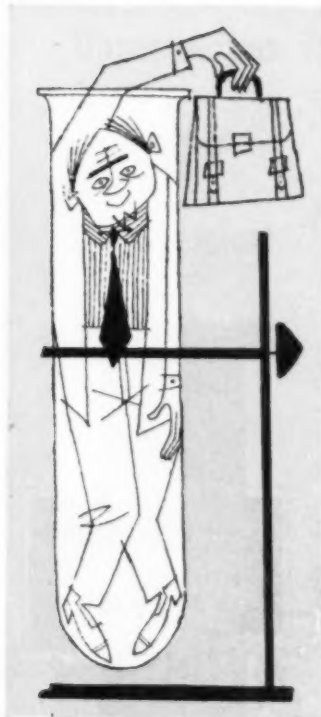
### Time Was When . . .

About 40 years ago the chemical industry in the United States consisted mostly of the manufacture of the basic acids and alkalis and a few of their logical derivatives. Production of organics was small indeed, for each time an organic chemical enterprise of any consequence reared its tender head, European chemical combines found some means to chop it off.

World War I had just started in Europe and, although the United States was not drawn into it until sometime later, its impact was already being sorely felt here in America.

Our people were shocked into a realization of their dependence upon European sources of supply, chiefly those in Germany, for dyes and pigments, to support our textile and paint industries and for certain synthetic pharmaceuticals to preserve the health of our citizens. We were in a sorry plight.

However, World War I required the domestic manufacture for smokeless powder and high explosives of some organic intermediates that were also the raw materials for a limited num-



ber of the simpler dyes and drugs. Thus came into being the first real effort to establish in this country a comprehensive and self-sufficient organic chemical industry, despite the lack of an adequate number of American trained chemists, engineers and chemical engineers to man it.

Most people are familiar with the remarkable development since then, when, under the protection of import tariff provisions, this country was able to throw off the yoke of dependence upon the chemical manufacturers in Europe.

Following World War I America settled down to the peacetime production and selling of inorganic and organic chemicals. Along with all other industries, the chemical business experienced an active period of about two years while the domestic and world-wide markets, starved of supplies during the period of diversions to war needs, bought generously to replenish their empty shelves.

Selling in those days was largely conducted by men who, by the accepted definition of the times, were called salesmen. They were fine, hearty, personable fel-

lows with all the attributes of glibness and effrontery that were considered essential qualifications of salesmen of that day. Many of them were brokers, sales agents or factors who had been accustomed to importing and reselling goods. There was no appreciable number of chemists among them. In fact few had even the remotest idea of how chemicals were made or the significance of their properties and specifications and they had even less knowledge of their practical or potential uses.

During that short span of excessive material shortages anyone could sell anything and so that corps of salesmen could easily sell chemicals. Since they could not pronounce the names of the chemicals, all they had to do was to toss a price list before a buyer who would then voraciously make out an order and those salesmen thought they had fulfilled their destiny.

However, luck does not last forever. For ill-prepared, and abortive efforts, retribution inevitably comes. It certainly hit the chemical industry. Orders dropped off, plants shut down, men and women were thrown out of jobs and executives became panicky.

Selling had not been done in a manner which would help build the chemical industry for the long term. Rather, had the business been handled on the basis of short-term opportunism.

### Beginnings of Reform

Then, about 1921, a sales manager made a trip around the country, with the salesmen in each of their respective territories, to call upon the customers who had theretofore been so generous in their purchases. All he heard was: "Your price is too high; your quality not good enough."

But meanwhile he received some deep impressions which led to a conclusion. This sales manager decided it was necessary to develop salesmen who could understand the customer's business and problems and who could teach the customers how to make something useful out of the chemical materials they bought.

So, his reasoning went: "Why employ laymen to sell materials, products and goods that require a technical knowledge of chemistry to demonstrate their usefulness?"

From then on the chemical industry turned more and more to the engagement of chemists, and men trained in other fields of science appropriate to their assignments, for the performance of the sales function.

During this evolution, men lacking a scientific education often continued to act as salesmen and were assisted from

time to time by technical demonstrators. Then the question arose: "Why employ two men to do one man's job?" Perhaps the very earliest recognition of this principle had occurred along about the year 1905 when the explosives industry started to train commercial salesmen to demonstrate the utilization of its hazardous chemical products. Even in those days the European dyestuffs manufacturers sent men here to service their products in American textile, paper, and leather mills but they mostly guild craftsmen who had learned application methods by rote rather than by scientific reasoning, seemingly, because employers did not want their representatives to know more about the technical details of the materials they sold than were needed for consumer purposes.

Fortunately, early in the growth of the organic chemical business in this country the farsighted acceptance of the need for salesmen-chemists and demonstrators, as well as scientifically equipped facilities to support them, resulted in a selling philosophy that has created technical service laboratories and has provided competent personnel to develop and promote the sale of chemicals to such large consumers as the rubber, agricultural, textile, petroleum and automotive industries as well as to the other chemical-using markets.

### Sound Selling vs. Smart Talk

Today, essentially, all of the chemical companies have established technical service and sales-supporting technical work. One corporation has 25 laboratories devoted to this type of work supported by 29 field laboratories. The total investment by the industry in such facilities, must run well into the tens of millions of dollars, which is one measure of how the industry regards the sales function.

It is now estimated that 70% of the average chemical company's sales staff is technically trained compared with probably less than 25% only 20 years ago and an insignificant percentage 30 years ago. This current mode of selling is epitomized in the slogan of one chemical manufacturer, namely, "Serving Industry through Practical Applied Science."

In short, when the chemical industry early found common peddling would no longer serve its needs, it turned to technical service selling of the highest caliber. To its credit and benefit, the chemical industry indulged less in smart phrasing and embraced more sound sales thinking; recognized selling more as a creative art and less as an imitative routine; and committed itself to selling more by plan and less by guess.

One chemical executive is authority for the statement that *only one out of 20 research projects yields a useful result*. At times, it seems to me that the score is much lower. For example, during recent years more than 500 new compounds were synthesized and extensively tested to ferret out only one which was efficacious for satisfying a human need and it still fell short of being the ideal product for the purpose.

A prominent marketing executive has reported that *nine out of ten new products launched on the market fail to survive*. His survey covered a broad cross section of commercial activity, rather than chemicals specifically.

However, for present purposes, both figures are accepted as applying to new or improved—and therefore somewhat new—chemical products. Simple multiplication reveals that only one half of one per cent of the products sought for through research eventually withstand the scorching test of the market place. That is a skinny margin of safety upon which to depend for producing the revenue needed to pay for all the costs of doing business. To the uninitiated that result must seem to be a terrible reflection upon chemical research and salesmanship. It must impress them as a terrific waste of time, money, facilities and effort.

To the initiated, it means that research must do better and so must sales in the opinion of "sophisticated" sales managers who are fully conscious of the need to reduce early obsolescence and mortality of new products through better market analysis, better sales planning and better field merchandising. In other words unless the new product is a pure, stable compound of precise chemical structure, the chances are that it will go through a long period of modification, improvement and adaptation before it will be accepted in a buyer's market.

It is in this period that the sales function is important in analyzing and evaluating for customers' purposes the adequacy of a new or improved product. Sales must be proficient in demonstrating to research and manufacturing the shortcomings of a product and should be technically capable of proposing ways in which the deficiencies may be overcome.

In 1951 sales of the chemical industry aggregated roughly \$18 billions. Few chemical products sell themselves. They must be sold by superior men and methods.

### The Sales Function

The efficient and profitable selling of such a prodigious quantity of goods is a stern responsibility that attests the

importance of the sales function in the chemical industry. And that function will become still more important when defense spending reaches a plateau, recedes and billions of buying power are taken out of our economy.

The soundness and productivity of our selling methods will then meet the test of sustaining our research and manufacturing capacity; of making a profit under adverse conditions; and of contributing greater service in supplying human needs.

To summarize, the manifold function of sales is to:

- Search out the prospect.
- Arouse interest.
- Demonstrate utility and value.
- Create preference and inspire confidence.
- Make a specific proposal.
- Close the sale.
- Service the delivery and use or consumption of the goods sold.
- Offer the customer new or improved products and better or more efficient methods for using them.
- Recognize the need for new or better products and services so as to cooperate with finance, research and manufacturing toward creations, improvements and expansions.
- Evaluate the trend of business activity so as to forecast to finance and manufacturing the rate of future operations.
- Appraise the needs of a growing and changing population.
- Be alert against the assailments of and displacement by competition, and,
- Keep everlastingly the customers' favor and business.

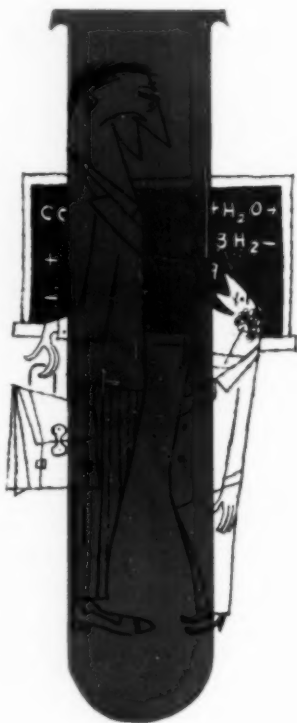
Charles F. Kettering says he does not know exactly the draw-bar pull of a Diesel locomotive but that he does know it has pulled a lot of railroads out of bankruptcy.

Neither does this author know the horsepower of an efficiently managed, progressive sales organization but he does know it will keep a corporation not only solvent but healthy, prosperous and growing! That is how important the sales function is!

Finally—

For a business career that is never monotonous, always interesting, exciting and stimulating at times, socially pleasant, financially rewarding, packed with the privilege of service to mankind, and withal thoroughly satisfying perhaps many more chemical engineers will consider entry into sales work.

If they do, and decide favorably, they should adopt as their creed that selling is the life-blood of the American enterprise system; also that a wise salesman knows that a good sale must be a good buy!



# Opportunities in SALES

for

## Chemical Engineers



**T**HIS paper covers the high spots of one of the four major phases of any chemical business, namely, selling, and highlights the opportunities for trained chemical engineers in that phase.

Webster's dictionary defines a salesman as a man who sells goods or merchandise. Selling, in its broadest sense, however, means much more than this. The course of civilization has been changed many times because somebody sold an idea to somebody else. For example, Columbus sold an idea to Queen Isabella, received money and ships, and here we are. The sale of vast quantities of merchandise is frequently preceded by the sale of an idea. I think the starting point of all selling, however, is selling

yourself. With many men this is probably a constant subconscious procedure. So, you see, every man is to a greater or less degree a salesman to begin with, and there are many with latent potentialities in this humble art.

Unfortunately, our engineering schools in turning out chemical engineers fail to point out to their graduates the varieties of opportunities open to them in industry, particularly the chemical industry. Whoever heard of a course in salesmanship or selling chemicals as part of the curriculum of a chemical engineering school. Chemical engineers are usually placed in industry, chiefly with the chemical companies, long before graduation and absorbed

into research and production. This often means readjustment for the individual later on and loss of time for him and the company who hires him. As it now stands, it remains for a chemical engineering graduate to find out for himself sometime, somehow, that he can have a career in selling chemicals.

There is no industry more technically complex than the chemical industry. It is big business today and constantly growing bigger. To survive and continue to grow, its products must be consumed—sold. Chemicals being what they are, there can be no doubt that they are sold fundamentally on the basis of facts—technical facts. These facts are the chief commodity that a chemical engineer has to sell; their presentation must precede or at some point be a part of the selling of a chemical. The chemical engineer, therefore, is best fitted to do this job of selling. He knows most about chemicals, how they are made, their properties, and where and how they are used.

A canvass of the leading chemical companies today will reveal their appreciation of the chemical-engineer salesman. They now require a trained background in chemistry or chemical engineering in every man added to their sales personnel. Young men entering chemical companies in sales work, who are expected to grow with the company and build themselves into its future, must

J. C. Leppart, executive vice-president of Mathieson Chemical Corp. joined the company in April, 1948, as a vice-president. A few months later he was appointed executive vice-president and director. A graduate of Cornell University as a Bachelor of Chemistry (chemical engineering), he went to the Solvay Process Co., Syracuse, N. Y. From 1921-1930 he was assistant manager of specialty product sales. In 1930, he joined the Columbia chemical division of Pittsburgh Plate Glass Co. as assistant director of sales, soon becoming director of sales. Aiding the war effort, Mr. Leppart was chief, chlorine alkali section, and assistant chief, inorganic chemicals division, War Production Board. In 1945 he was located with the Southern Alkali Corp., Corpus Christi, Tex., as assistant to the operating vice-president, and before going to Mathieson he became associated with Prior Chemical Corp., New York, as vice-president. Mr. Leppart serves on several government committees, such as Chemicals Industry Advisory Committee.



J. C. Leppart

have this background in order that they and the company will be able to keep pace with this fast-moving industry.

At this point, one can conclude that there are opportunities for chemical engineers in selling chemicals because the companies themselves need such engineers and, in fact, insist upon men with such a background as they build their sales departments for the future.

Naturally when considering entering the selling game, one does not know whether he can sell chemicals or not; and since actually getting the orders is the crux of the matter, the main yardstick of success, it is a most important question. This paper cannot answer that question for you. I can say to you, however, that if you have a chemical engineering background, a good personality, an alert, inquisitive and analytical mind, the ability to think and act quickly, and a strong competitive urge, you can sell chemicals if you are willing to follow certain fundamentals, which any good sales department can teach you, and if you are willing to work intelligently and hard. Since the greatest teacher of plain sales fundamentals is experience, you can be sure of increased effectiveness in this phase of selling chemicals in proportion to the speed with which you can gain experience in the field.

The next question you will probably ask yourselves is whether or not you can use your talents to advantage in this field of industry, and what is involved in so doing. Webster's definition of a salesman, which was mentioned previously, may be basically correct but is wholly inadequate to describe what a chemical salesman must be or do if he is to be successful. Webster doesn't define a "chemical salesman." A chemical salesman must do much more than call on buyers, get orders, and negotiate contracts. I am assuming that this man wants to rise to positions of responsibility in his company's management, aspires to take part in the guiding of its destinies, desires to use his selling job as a means of developing and broadening himself, thereby gaining the recognition that brings about the attainment of these objectives. This is the man to whom this paper is addressed and he must do the following things:

He must be posted on his company's production and shipping problems.

He must know his products thoroughly, their quality, their properties, and how they are used or may be used in various industries.

He must know the competitive situation surrounding each product he sells, nationally in a general way and intimately in his territory; who the producers and sellers are; the price situation; where his competitors are selling and in what quantities; what advantages he has over them, if any; what

changes his company should effect to make his products competitive or superior.

He must develop an accurate picture of his territory potential. What is the total consumption of his products in the territory? How much of this business does he have, and who has the rest of it and how much?

He must have a current general working knowledge of each industry that is a user of his products so that he can determine the trends in his various outlets and be quick to sense new sales potentials as developments occur.

He must learn something about all the chemicals bought in his territory other than those produced by his company in case an opportunity presents itself for his own company to produce one or more of such advantageously.

He must learn some of the manufacturing problems of the industries in the territory involving the use or possible use of chemicals; in this way he can visualize a solution by the use of his own or new products his company might make.

He must understand distribution in its broadest sense which means packaging, loading, transportation and materials-handling from his plants to his customers' consuming processes. Today this is most important.

He must keep abreast in a general way of developments and progress within the chemical industry as a whole through the trade papers and selected trade and technical organizations; thus he will understand and talk the language of the industry.

He must place his knowledge and information, as acquired, in the hands of his company promptly through conferences or reports; in turn he logically can expect much help from headquarters.

He must know the effects of the laws of our land on his company's operations and his customers, and be prepared to operate within their scope. Today he must know, in addition, the meaning and significance of limitation orders, allocation orders, price-ceiling regulations and the like.

He must know when and how to use to advantage his company's research department, its technical service, operating talent, traffic men, its purchasing men, etc., in order to consummate sales.

He must cooperate at all times with other branches of the company with which he may have contact, and integrate his activities with other sales personnel as part of the over-all company team.

He must exercise good business judgment in placing his company's products, looking to the future as well as the present.

He must be alert to the credit position of his buyers.

Studying these requisites of a chemical salesman, one can readily see the ample opportunities for the full use of the special talents of the chemical engineer in the consummation of a proper chemical selling job, and a further chance to expand those talents in a direction fully as important, and as interesting and challenging as in production or research, or other branches of the industry. This writer wants to emphasize



that "selling chemicals" is no ordinary selling job.

What about advancement? How secure is the selling function and where can it lead? Let us expand a little on why the chemical industry needs more men with chemical background and training in the selling end of the industry.

In any expanding industry, the sales personnel must be enlarged at least proportionately. The chemical industry is definitely a "growth" industry. Three chemical companies are now in the list of twenty-five largest United States corporations. During the decade 1940-50, eleven of the major chemical companies showed a combined sales growth of 248%. It is expected that two billion dollars will be spent during the next two years in expanding the production of basic chemicals alone. The output of new chemicals will undoubtedly continue at an accelerated rate. The sales problems of a chemical company under these conditions will be more difficult than ever, and more chemically trained men will be required to move the production and find outlets for the new chemicals.

The chemical industry, to repeat, is technically complex. It manufactures thousands of interrelated products of varying degrees of importance to our industrialized civilization. The "product and process turnover" is rapid. In many cases, substitutes and replacements appear before the initial product is thoroughly established. Nothing is ever static. So, nothing is ever static in sales, and the chemical salesman will have his hands full at all times keeping up with the changes. Confidence coming from a thorough technical knowledge of all the factors involved will enable the chemical salesman under these conditions to move quickly and effectively, and to act decisively in the face of opportunities which may be here today and gone forever tomorrow.

The industry lives on its basic chemical production and expands on the fruits of its research. For example, it is reported that Du Pont, our largest chemical company, receives more than 60% of its gross sales revenue from products unknown twenty years ago. Furthermore, Du Pont recently invested thirty million dollars in facilities for the study of new products and processes. Every chemical company now has an ever-expanding research program. Even the best-trained technician has difficulty keeping pace with the developments of chemical research. The technically untrained salesman will be hopelessly lost.

Fluctuations in the delicate balance of supply and demand in the case of any one chemical or sometimes a group of chemicals, frequently create difficult problems for the producers. Changes in

the national or world picture create shortages and surpluses as exist in many of our chemicals produced today. The solution of this type of problem rests largely with recommendations that the sales department will make to top management, and it is during periods of this kind that sound selling based on good business and technical judgment often can make or break a company from both a monetary and public-relations viewpoint.

Future chemical management will come in part from well-trained chemical salesmen. A chemical company must sell to succeed. Selling is the catalyst which brings together those two unreactive components, production and consumption. Selling is the act responsible for the transfer of revenue from buyer to supplier. This revenue is the measure of a company's success or failure. Therefore it is quite natural for those whose experience has been primarily in the selling field, to rise above the ranks and ultimately assume important posts at the management level. The day-to-day contact with the problems of selling chemicals develops a broad foundation upon which the responsibility of company policy decisions can safely be placed.

Up to this point this paper has been concerned with the selling of chemical products which have been established as production items by a company. The manufacture and sale of these items furnish the profits which permit the company to stay in business. By expanding production and sale of these same items, the company can grow but it can grow also by developing new chemicals from research, and producing and marketing them. This is a somewhat different and extremely important phase of chemical selling, namely, the translation of the products of research to marketable items. This calls for a fact-finding and promotional group who can take a product from research, study its properties and visualize where it can be consumed, and whether or not it can be marketed at a profit to the company. This, of course, requires men with chemically trained backgrounds, a wide knowledge of all the industries and places where chemicals are consumed, a high degree of imagination and technical-sales skill, and an extraordinary ability to cooperate with such branches of the company as research, production and day-to-day selling. The organization and operation of this kind of a group could well be a separate subject for discussion. It is mentioned here as an opportunity for chemical engineers who have or can develop sales talent and also because it is a vital part of the problem of selling new chemicals.

Now how does the chemical engineer-

salesman with all his qualifications and his sense of selling objectives progress along the path of increasing responsibility and opportunity? He may start as a junior salesman handling relatively insignificant accounts or territories, or he may be assigned as a technical specialist promoting the sales of new products. As he gains in experience he may move to a larger territory, or take on more important account responsibilities. Subsequently he might become a district sales manager in the field or perhaps a product sales manager in the home office. From there, he has the opportunity to advance to positions in top sales management of the company as an officer in complete charge of all the company's sales problems. The final achievement can even be the presidency of the company, and several examples could be cited of chief executives of chemical companies who reached that position mainly via the sales route, and it is more than evident that any top management that is not alert to and conversant with its sales problems, will not reach its full measure of success.

This author believes the chemical industry is the most important of all industries for without chemicals there would be no other industries. Steel, aluminum, other nonferrous metals, petroleum and the like, could not exist without chemicals or chemical processes within themselves. In one way or another, chemicals are used in almost every industry, touch every phase of human existence, are responsible in large measure for our industrial progress, and for many new material things to improve our ways of life.

Again I must say that the function of distributing our chemicals both the old and the new is a basic one. Successful chemical selling offers a challenge equal to that of any phase of the chemical industry and a chemical engineer should not undertake it unless he has energy and will to pursue it relentlessly with vigor, to live it, to dream it. There are rewards in money, in personal satisfaction, in human relationships, in friends. You will gain an understanding of many industries—an opportunity to create as well as produce. You can advance as far toward top management as your results and understanding take you, which is in proportion to the effort you make. This means a career in selling which young chemical engineers should consider well.

#### Acknowledgment

Acknowledgment is hereby given to J. O. Logan, sales manager, Industrial Chemicals, Mathieson Chemical Corp., for his assistance in preparing this paper.

# DESIGN AND CHOICE OF EQUIPMENT FOR GAS DEHYDRATION

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THE rapid expansion of the natural gas industry in the postwar period has placed increased emphasis upon production and process methods. Consequently, new methods have been devised and existing ones modified.

Many of these recent advances have been made in the field of gas dehydration in order to reduce operational problems and to ensure an uninterrupted supply of gas in the transmission systems. Although these new techniques of dehydration are being used more extensively in the natural gas industry, some of them at least should find application in other fields where dehydration is a problem.

The large majority of all gas in this country is dehydrated by one of the following four methods:

1. Dry desiccant plants
2. Glycol absorption plants
3. Expansion refrigeration or low-temperature plants
4. Glycol injection plants

The latter two systems have been developed in the natural gas industry

because they not only dehydrate the gas but give a condensate recovery greater than that obtained by separation at atmospheric temperature. Because these both involve expansion, with a substantial pressure drop, their use in other industries will be somewhat limited, particularly where pressure is obtained by means of compression. In other than the natural gas industry, however, the systems for the dehydration of gas by means of adsorption and absorption are applicable.

The final choice as to which method of dehydration is the best for a particular job depends on two factors—the cost factor and the determination of which type of unit will meet the specifications set up for the process. Because of the number of variables which are present in dehydration problems, no one unit is applicable in all situations, and both of these factors must be considered before a final choice is made. This discussion is the result of a detailed investigation into the dehydration of gas to assist in evaluating the systems. The figures

shown are for large commercial systems and do not apply to drying on a laboratory scale.

In addition to the systems chosen for study, a large quantity of gas is dehydrated by compression and mechanical refrigeration. A compressor, however, is not considered as a dehydrator since any dehydration obtained is a secondary consideration. In fact, the water removed during compression is troublesome because of the increased heat-transfer and scrubber requirements following each stage. As a means of dehydration alone compression is economically unsound.

On the other hand, mechanical refrigeration is an excellent means of dehydration, but economic considerations alone limit its use to those applications where other systems will not meet process specifications and/or have other limitations. When used in the natural gas industry, the goal is liquid hydrocarbon recovery rather than dehydration alone.

For convenience the systems chosen for study are listed separately.

## Dry Desiccant Dehydration

Many reliable dry desiccants have been developed for gas dehydration; they may be subdivided into two classes—the oxides of aluminum such as florisil, activated alumina, and various grades of bauxites, and the gel-type beads. The most common of the latter have been S/V Sovabead and silica gel although a new bead made of alumina gel is now in the development stage. The gels and alumina vary in their capacity, the former having a higher affinity for water although they are correspondingly more expensive. Their comparative properties have been widely discussed (1, 3).

A summary of the properties and limitations of dry desiccant plants is shown in Table 1. A properly designed plant, regardless of the type of desiccant used, will give virtually bone-dry gas

TABLE 1.—SUMMARY OF OPERATING CHARACTERISTICS, DRY DESICCANT DEHYDRATION

Recommended operating range:	At temperatures below 125° F. in order to obtain highly efficient adsorption. Any natural gas should be above its hydrate point before entering the system. Pressures up to 3000 lb./sq.in. gage have been used with success.
Degree of dehydration:	Essentially bone-dry gas produced (less than 1 lb. of water/1,000,000 cu.ft.). Properly designed units for service such as natural gas give dew points less than 0° F. at the end of the cycle.
Advantages:	<ol style="list-style-type: none"><li>1. The low exit dew point obtained.</li><li>2. Effective dew-point depressions over a wide range of operating conditions.</li><li>3. Readily adaptable, at relatively low cost, for drying small amounts of gas where batch operation is satisfactory.</li><li>4. Compact.</li><li>5. Additional hydrocarbon recovery over that obtained by glycol dehydration reported by some natural gas operators.</li><li>6. In some instances increase of rated capacity by by-passing some wet gas around the unit and combining with dry gas, where the dry-type units give dew points lower than those needed or specified.</li></ol>
Disadvantages:	<ol style="list-style-type: none"><li>1. High relative initial investment (see Figure 9).</li><li>2. In some installations, subject to relatively frequent and expensive desiccant replacements due to poisoning.</li><li>3. Pressure drop higher than with liquid systems, which increases the compressor requirements. The horizontal chamber described reduces this pressure drop substantially.</li><li>4. Decline of rated capacity of the unit with pressure.</li><li>5. At flow rates below rated capacity, regeneration heat load high in relation to amount of gas processed. (The compartmented vessel discussed reduces this requirement as the load decreases since only part of the bed may be used.)</li></ol>

(less than 1 lb. of water/1,000,000 cu. ft.) at temperatures up to 125°F. and pressures to 3,000 lb./sq.in. gage. As shown in Table 1, this type of plant has several serious disadvantages, among which are relatively high cost, high-pressure drop, and the potential poisoning of the desiccant by materials such as heavy oil. Many different modifications of this type of plant have appeared in an attempt to minimize these disadvantages. Figure 1 is the flow sheet of a new development in the field which utilizes horizontal vessels with transverse flow of the gas around a baffle. This type of construction substantially reduces the pressure drop through the bed and the amount of packing attrition since low velocities are maintained over a large cross-sectional area.

**Apparatus.** With reference to Figure 1, the wet gas enters the unit and flows through a pressure-reducing valve to the inlet scrubber of the sorber beds. Just upstream from this pressure-reducing valve, gas which is taken off for use in regeneration of the sorbers passes through a heater, through the bed to be regenerated, and into a heat exchanger, where it is cooled by the main dry-gas stream leaving the plant. In this heat exchanger the regeneration gas is normally cooled from about 350° down to 125° F., thus condensing the water that was picked up in the regenerating bed. The regeneration gas then enters the main gas stream going to the scrubber just downstream from the pressure-reducing valve. The amount of regeneration gas is controlled by an orifice plate in the regeneration line, and enough pressure drop is taken on the main line to pass the required amount of gas through the beds. After the bed has been dried, the gas is by-passed around the heater with a three-way valve with a time-cycle controller, which cools the regenerated bed before the switching of the cycle.

The main gas together with the gas from the heat exchanger enters the scrubber, at which point the liquid in the main wet gas, plus that condensed in the heat exchanger, is scrubbed and dumped. The scrubbed gas then proceeds to the drying vessel, entering through one of the heads into a header which has openings into the vessel's compartments. The inlet head of the sorber is so arranged that secondary separation is obtained if necessary. The gas then flows around the baffle and out through a manifold, from where it goes through the heat exchanger and into the transmission system.

**Compartments.** The use of the compartments in the sorber vessel not only forces good distribution between the sorber gas and the desiccant but gives this particular sorber a great deal of flexibility in balancing out the head load on the system. At those times when the plant is not running at designed capacity, one or several of these compartments may be shut off and only a portion of the bed used as required. This reduces the heat load for regeneration since only that portion used needs to be regenerated. The design also reduces refluxing during the regeneration cycle since heat is transferred through

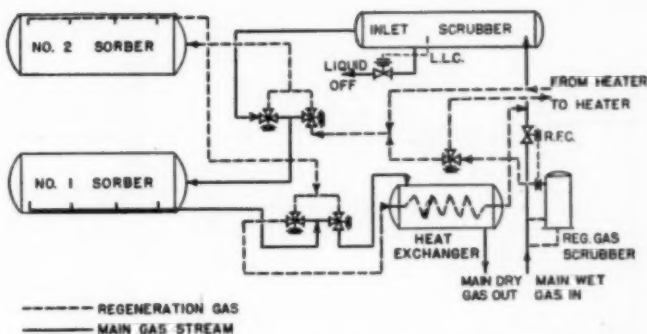


Fig. 1. Flow sheet for a dry desiccant plant with horizontal sorber vessels.

the baffles and reduces the temperature gradient across the bed.

**Break-point Curve.** Figure 2 illustrates the effect of gas velocity on the type of break-point curve obtained. The solid line shows the results obtained on a horizontal unit with a gas velocity of 15 ft./min., based on the average cross-sectional area of the vessel. The characteristic sharp break point of the standard dehydrator vessel is not obtained until after the curve exhibits a gradual increase. The type of curve shown is obtained because the gas flow is so distributed that dehydration occurs at low velocity over a rather wide area. Toward the end of the cycle, when the bed has been progressively saturated, the effective time of contact between the gas and the remaining dry solid is very small, and dehydration efficiency therefore decreases. With lower velocities the last remaining portion of the bed

is used to greater advantage, and the drop in efficiency is not quite so sharp.

This curve, however, is primarily of academic interest inasmuch as economic and process considerations usually limit design velocities to between 25 and 45 ft./min. In maintaining these velocities, however, the horizontal sorber has merit, since with a given size of vessel the cross-sectional area parallel to the major axis is greater than that perpendicular to it. For example, a vessel with  $L/D$  ratio of 4:1 has about a two-and-one-half times larger cross-sectional area for transverse flow around a baffle at the center line than it would have if used as a conventional vertical tower.

### Glycol Absorption Dehydration

The present triethylene glycol dehydrator is an outgrowth of research and development which proved it to be a liquid desiccant superior to those pre-

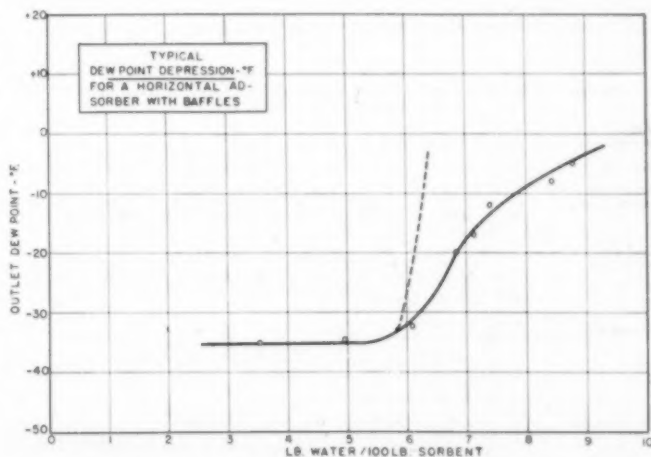


Fig. 2. Typical break-point curve for horizontal baffled sorber with transverse flow.

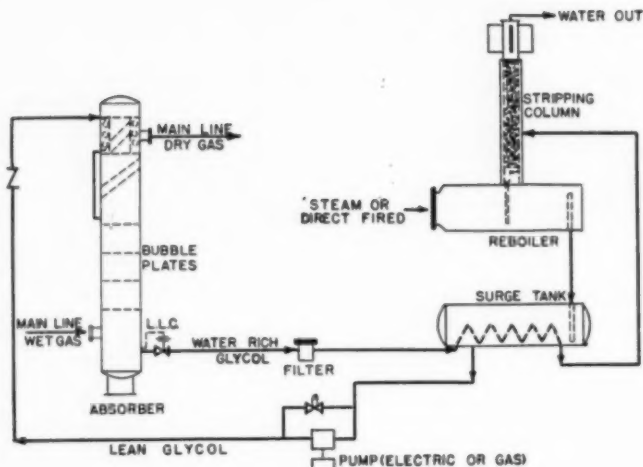


Fig. 3. Flow sheet for a triethylene glycol absorption dehydrator.

viously available. In the past fifteen years a number of absorption systems utilizing glycerine, calcium chloride, and diethylene glycol have been built, with the latter predominating. Although di- and triethylene glycol are similar liquids, the latter has two important advantages as a result of its higher boiling point; the vapor pressure is lower, and higher concentrations are easier to obtain in the stripper column. The former advantage reduces vaporization losses while the latter enables greater dew-point depressions to be obtained. When properly applied, these units give from 35 to 85°F. dew-point depressions.

A flow diagram of a triethylene glycol system is shown in Figure 3. The absorber is unique in that about half the total length is taken up by a spray con-

denser-heat transfer section. Even though vaporization is small, this protection is the secret of the low entrainment losses experienced, which average about 0.025 gal./1,000,000 cu.ft.

**Apparatus.** The internal heat-exchange section, used on all except the very large units, cools the glycol down to temperature before it enters the top tray of the absorber. The water-rich glycol leaving the bottom of the absorber then passes through a filter to a preheater, where it exchanges heat with the hot bottoms from the reboiler. After being preheated, the hot solution then enters the atmospheric still column.

The glycol flows by gravity down through the still column into the reboiler and from there through an overflow pipe into a glycol surge tank and heat exchanger, where it is cooled by the cold, rich glycol from the bottom of the absorber. The reboiler may be direct fired or use high-pressure steam.

From the surge tank the glycol is pumped to a heat-exchanger coil in the top of the absorber, at which point it is further cooled by the main gas stream. From these coils it flows on to the top tray of the absorber.

This type of unit is also entirely automatic and utilizes only three controls: the liquid-level controller, the speed control on the pump, and a temperature controller on the reboiler. The dew-point depression depends on the absorber contact temperature, the composition of the lean glycol, and the circulation rate.

This still column requires only that amount of reflux supplied by air-fin coolers on the top since water and triethylene glycol have such widely separated boiling points. Therefore little rectification is required in the top of the column, and little positive control of the reflux is needed.

**Advantages.** These units have been used successfully at pressures up to 2000 lb./sq. in. gage and at temperatures up to 100°F., although they are not recommended at temperatures above 90°F. if the gas is to be dehydrated to meet normal pipe-line specifications, which are usually 7 lb. of water/1,000,000 cu. ft. The specifications and limitations of this unit are summarized in Table 2. The data shown were obtained during an extensive survey of over 100 units. A unit such as this utilizing triethylene glycol is recommended over one using diethylene glycol owing to the low initial cost. Other advantages are the ease with which a high concentration of glycol may be obtained and the low vapor pressure of triethylene glycol, which in the normal plant-operating range is only one-tenth that of diethylene glycol. The very small losses experienced are the direct result of the low vapor pressure of triethylene glycol and the very efficient spray condenser.

The still column is designed to give not less than 98.5% triethylene glycol by weight in the lean solution. In order to adhere to this figure and control the water concentration of the solution to the still column, not less than 3 gal. of glycol is circulated/lb. of water absorbed. In normal plant operation the flow rate is adjusted to this figure, based on rated capacity, and maintained constantly regardless of the actual flow rate. A survey of existing installations showed flow rates of from 3 to 7 gal./lb. of water, with about 4 gal./lb. being the predominant figure.

The effect of the glycol concentration in the solution entering the absorber on the dew-point depression, all other factors remaining the same, is shown in Figure 3 (a). The depressions shown are for a 4-plate bubble-cap column with a circulation rate of 3 gal./lb. of water removed.

In effect, a complete set of curves may be drawn which appear to coincide at the upper left end. The vertical position of the curve on the plot depends

TABLE 2.—SUMMARY OF OPERATING CHARACTERISTICS, TRIETHYLENE GLYCOL ABSORPTION DEHYDRATORS

Reboiler temperatures:	375°F. recommended.
Flow rates:	In normal service about 3 gal. of glycol circulated/lb. of water removed.
Recommended operating range:	At temperatures below 90°F. and preferably at or below 80°F. At higher temperatures greater contact must be supplied. Units have been successfully operated up to 2000 lb./sq.in. gage.
Degree of dehydration:	Dew-point depressions from 55° to 85°F. normally obtained with standard units. The minimum dew point is about -15°F., regardless of the contact temperature, with a standard unit (about 1.0 lb. water/1,000,000 cu.ft. at 1000 lb./sq.in. gage).
Advantages:	<ol style="list-style-type: none"> <li>1. Low initial and operating cost.</li> <li>2. Pressure drop very small.</li> <li>3. May be used with materials that might poison dry desiccant.</li> <li>4. Compact and reasonably light, which facilitates moving.</li> <li>5. Only three controls, all of which are sturdy and require practically no maintenance.</li> <li>6. Liquid carry-over negligible.</li> </ol>
Disadvantages:	<ol style="list-style-type: none"> <li>1. Dew-point depression less than with dry desiccant.</li> <li>2. Some foaming tendencies exhibited by glycol in the presence of some of the heavier hydrocarbons. Anti-foaming agents, in small concentrations, alleviate the situation.</li> <li>3. In most applications, inlet scrubber necessary to protect glycol from excessive water dilution.</li> </ol>

on the circulation rate and temperature of contact.

### Expansion Refrigeration or Low-temperature Separation

Low-temperature separation is now being used extensively in the field of natural gas dehydration, since not only is the gas dried effectively, but in many cases sufficient additional condensate recovery is obtained to more than pay for the cost of dehydration. These units when used in conjunction with stabilization have increased condensate recovery as much as 35%. It is then possible to make natural gasoline by the proper processing of this condensate liquid.

The system may be modified to handle variable process conditions. Flow sheets for two systems are shown in Figures 4 and 5. Since most natural gas gathering and the newer transmission lines in this country operate at between 700 and 1000 lb./sq.in. gage, the unit in Figure 4 is best suited for service where the pressure before expansion exceeds 3000 lb./sq.in. gage and well-stream temperatures do not exceed 100° F.

**Apparatus.** With reference to Figure 4, the high-pressure well stream enters the heat-exchanger coil in the bottom of the low-temperature separator where it is cooled by the cold liquid and proceeds to the free-water knockout, where the liquid water is removed. The gas and condensate leaving the free-water knockout are then throttled across a valve into the top of the low-temperature separator. On expansion, which is substantially adiabatic, the gas is cooled, and the hydrocarbon hydrates, plus the liquids, fall to the bottom, where the liquid is heated and the hydrates are melted by the hot gas stream inside the helical coil. The liquid then leaves the bottom of the separator, from where it proceeds to a stabilizer or stage separation. The use of this system is limited to those applications where sufficient pressure drop is available to give the necessary temperature drop and the corresponding dehydration.

The dew point of the effluent gas corresponds roughly to the temperature of the low-temperature separator. Some reports show it to be 10° to 14°F. lower, but an exact figure is difficult to predict since an accurate temperature is hard, if not impossible, to obtain. It is usually good field practice to assume that the dew-point and separator temperatures are the same.

Another modification of a low-temperature system is shown in Figure 5, where a regenerative heat exchanger is added between the separator heating-coil outlet and the inlet to the free-water knockout. When properly designed, this system will give specification gas until the pressure differential declines to approximately 1200 lb./sq. in. gage. At lower pressures any attempt to produce specification gas (7 lb./1,000,000 cu. ft.) will be limited by hydrate formation

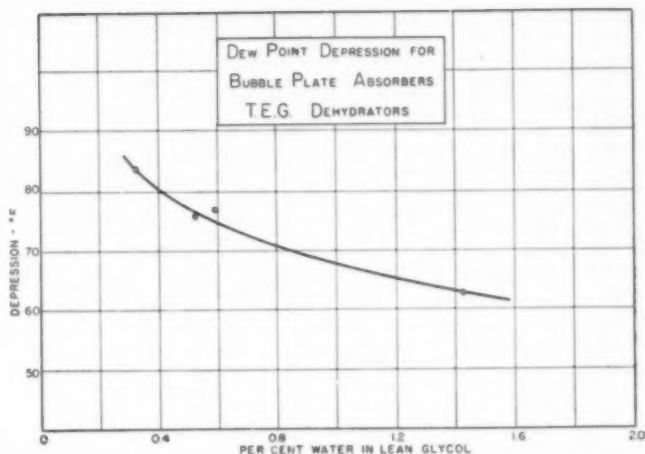


Fig. 3(a). Effect of water concentration in the lean glycol stream on dew-point depression.

in the heat exchanger of the system shown. It may be modified to function effectively at lower pressures, however, by the addition of the glycol-injection facilities shown in Figure 7.

Figure 6 shows curves, based in part on experimental data, which predict the amount of temperature reduction ex-

pected for a given pressure drop. These are based on the expansion of a gas containing approximately 20 bbl. of condensate/1,000,000 cu.ft. The temperature drops obtained from these curves may be corrected for gases with a different liquid content by reference to Table 3. The corrections are based on the

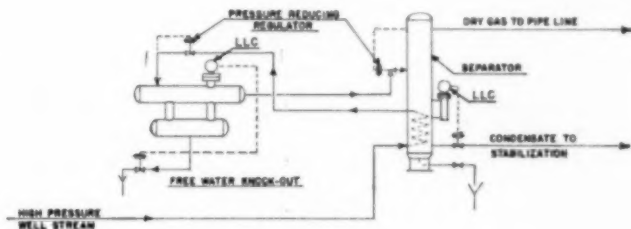


Fig. 4. Flow sheet for a standard expansion refrigeration system.

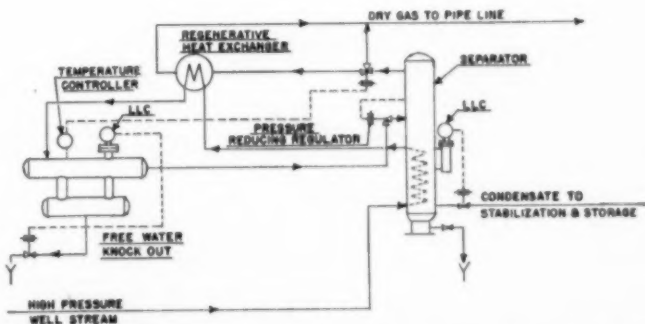


Fig. 5. Flow sheet for an expansion refrigeration system with regenerative heat exchanger.

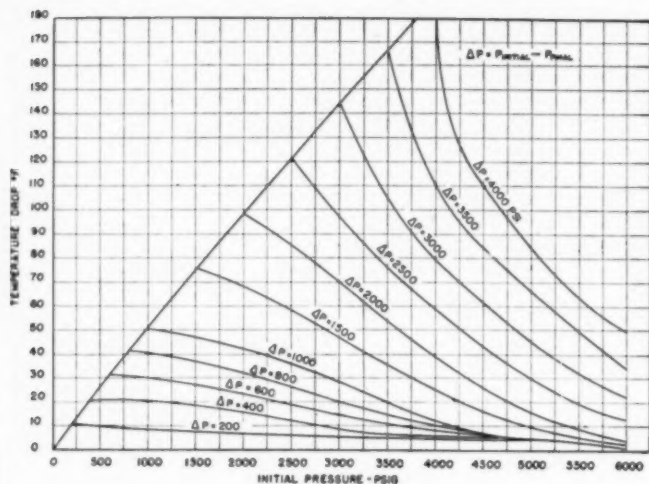


Fig. 6. Temperature drop accompanying pressure drop on expansion of natural gas (see Table 3).

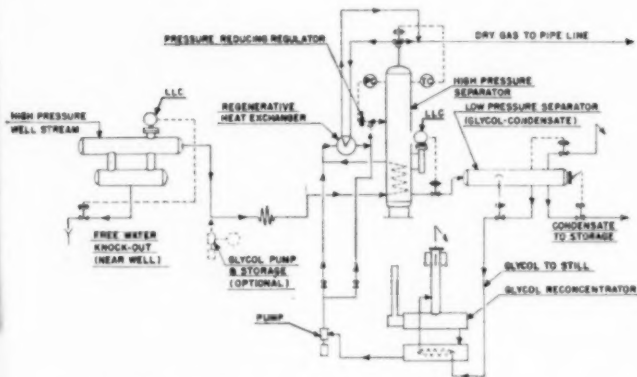


Fig. 7. Flow sheet for expansion refrigeration system as modified for glycol injection.

TABLE 3.—APPROXIMATE TEMPERATURE CORRECTION FOR HYDROCARBON LIQUID CONTENT OF A WATER-FREE WELL STREAM \*

Bbl./1,000,000 cu.ft. in stock tank	Temperature correction, ° F.†
0	- 10
10	- 5
20	0
30	+ 5
40	+ 10
50	+ 15

\* See Figure 6.

† Based on the assumption that 25% of the liquid is condensed on expansion and that 80% of the separator liquid is recovered in the stock tanks.

TABLE 4.—SUMMARY OF OPERATING CHARACTERISTICS, LOW-TEMPERATURE-SEPARATION UNITS

Recommended operating range:	Where available pressure drop is sufficient to give a dew-point depression comparable to the other systems. The necessary drop is usually about 1500 lb./sq. in. (see Figure 6). A wide range of temperatures may be handled by suitable modification of the equipment with the necessary heat-exchange requirements.
Advantages:	<ol style="list-style-type: none"> <li>1. Usually the least expensive system where a pressure drop is necessary in a process anyway.</li> <li>2. Increased revenue from most natural gas systems with the increased condensate recovery.</li> <li>3. Low dew points when sufficient pressure drop is available.</li> <li>4. Simple automatic operation requiring minimum attendance.</li> </ol>
Disadvantages:	<ol style="list-style-type: none"> <li>1. Restricted to those applications where a large pressure drop is available.</li> <li>2. Effectiveness lost as pressures decline. In this case it must be supplemented by other equipment.</li> <li>3. Danger of low-carbon-steel embrittlement and equipment failure if operated below <math>-20^{\circ}\text{F}</math>.</li> <li>4. Close control often necessary to prevent formation of hydrates prior to the low-temperature separator.</li> </ol>

assumption that 25% of the liquid is condensed on expansion and that 80% of the separator fluid is recovered in the stock tanks. The temperature drop predicted checks field data within 10% in most instances.

The flow in Figure 5 is the same as that in Figure 4 except that the temperature of the gas to the free-water knockout is reduced further by use of a portion of the cold-gas effluent from the top of the low-temperature separator. Since this system can operate at lower pressures, the extra cooling is necessary to compensate for that not obtained by expansion. The amount of cold gas used for cooling is controlled by a three-way valve which is actuated by a temperature controller on the free-water knockout, the remainder of this cold gas being by-passed around the heat exchanger. In all other respects, this system is identical.

The specifications and limitations of low-temperature systems without glycol injection are summarized in Table 4.

The system shown in Figure 7 is a further modification of that shown in Figure 4 for pressure differentials above 500 lb./sq. in. gage and temperatures slightly above the corresponding hydrate-formation temperature. Although moisture-content specifications might not be met by expansion alone, sufficient glycol may be introduced to lower the dew point to specification. Conventional low-temperature units whose effectiveness has been destroyed by a drop in field pressures may be modified in this manner.

With reference to Figure 7, the high-pressure well stream in this particular application enters the free-water knock-out directly and goes to the heat-exchange coil in the bottom of the low-temperature separator and the regenerative heat exchanger, previously described, from where it enters the choke or throttling valve. The glycol may be injected either upstream or downstream

from the heat exchanger, but if it is injected upstream the gas temperature may be lowered without regard to hydrate formation. If the low-temperature separator is servicing a number of wells, glycol may also be injected near the wells to prevent hydrate formation in the lines to the central system. With glycol injection the liquid from the bottom of the separator goes to a glycol-condensate separator, from where the glycol flows by pressure differential to a standard glycol still column and reboiler. After concentration, it goes back to the injection pump. The condensate from this separator goes to stabilization or storage.

In those cases where it may be justified from the condensate recovery, the desired refrigeration may be obtained mechanically instead of by expansion, as discussed previously. Such a system where used in conjunction with stabilization gives a plant for the production of natural gasoline and/or LPG products at a cost competitive with straight oil absorption. With such a system the cost for refrigeration is usually from 25 to 40% of the total cost.

### Glycol Injection System

Experience with systems such as the one shown in Figure 7 led to the development of a similar system known as glycol injection. It is designed for those applications where well pressures are expected to decline very rapidly or where sufficient pressure is not available to produce the necessary dehydration by expansion alone. Glycol injection has the advantage of being operable at lower temperature than other comparative units, which results in larger liquid recoveries. A flow sheet of this system is shown in Figure 8(19).

The gas enters the free-water knockout, which removes liquid water from the stream. Lean glycol is injected downstream from this knockout, and the gas then passes through the regenerative heat exchanger to a horizontal low-temperature separator. In this case the flow of cold gas through the exchanger is controlled by a temperature controller on the low-temperature separator. The oil and glycol from the low-temperature separator then proceed through a heater, where they are normally heated to about 70°F., before entering an oil-gas-glycol separator. The gas is vented or enters the plant fuel system, and the oil goes to stabilization or storage. From the separator the rich glycol goes through a surge tank, a heat exchanger, and then to a standard glycol still column. The concentrated glycol leaving the column goes to the injection pumps and is fed back into the system downstream from the free-water knockout. The specifications and limitations of

the system are shown in Table 5. Dew points as low as -30° F. may be easily obtained with the system even though the dew-point depression due to refrigeration is smaller than in the previous systems.

The low-temperature separator is a standard oil-field-type separator. No heat-exchange coils are used since the liquid will not freeze, owing to the presence of glycol as an inhibitor.

**Amount of Glycol.** In the average application it is necessary to inject from 0.2 to 0.4 gal. of glycol/hr./1,000,000 cu. ft. of gas, although the amount depends upon the available pressure drop in the system. As the pressure drop decreases, the amount of glycol that has to be injected to maintain specification gas increases proportionately. Tests run on one unit showed that while the temperature obtained by expansion was only 32°F., the outlet dew point, because of the glycol injection, was -13°F.

A series of investigations at the University of Oklahoma (10, 13) have determined the extent of the glycol losses in an injection system. These studies show that the loss is due to both vaporization and the slight solubility of glycols in light hydrocarbons. The vaporization loss is inversely proportional to molecular weight while the solubility loss is directly proportional. Although ethylene glycol is the least soluble of the glycols, its vaporization losses are by far the greatest. Triethylene glycol, on the other hand, is more soluble in light hydrocarbons although its vaporization losses are slight. Diethylene glycol has both solubility and vaporization properties which make its use a very good middle-of-the-road choice for all commercial applications in use at present.

A 70 to 85% solution of diethylene glycol is soluble to about 0.04 wt.% in light hydrocarbons. A more concentrated solution, such as used in absorp-

tion, is not advisable since the higher concentrations have a higher solubility. Although the glycol loss is slightly higher than with absorption systems, the cost is more than compensated for by the increased hydrocarbon recovery.

**Antifreeze Properties.** Glycol injection has also been successfully used, without expansion, to prevent freezing in gathering lines to central glycol dehydration plants. The use of gas-line heaters, at best, is inefficient since the temperature of the gas soon approaches that of the ground (17). In a normal system, for this application, it is necessary only to inject 2 to 3 gal. of glycol/1,000,000 cu. ft. of gas. The injection glycol passes into the bottom of the triethylene glycol absorber along with that which passes over the top of the tower and is regenerated in the same still column. The lean glycol stream is then split, part going to the absorbing tower and the remainder going to the injection pumps for reinjection into the lines. When injection glycol is used in this manner, however, separation must be provided upstream from the injection point in order to remove excess liquids.

The use of glycol injection for long gathering systems is open to question, particularly if there are marked differences in elevation. Even though the positive losses would still be small, a large quantity of glycol would be held in the system and make the initial cost of inhibitor quite large. In such a case well-head dehydration or heaters would probably be the better solution.

### Cost Comparisons of Various Systems

The range of the application of the systems discussed is wide enough so that in most cases there is more than one system that will give specification dehydrated gas. In this case the final choice of system is contingent upon economic factors. For the dehydration of

TABLE 5.—SUMMARY OF OPERATING CHARACTERISTICS, GLYCOL INJECTION SYSTEMS

Rate of injection:	Normal rate 0.2 to 0.4 gal./hr./1,000,000 std. cu. ft. of gas passed.
Type of glycol recommended:	A 70 to 85% solution of diethylene glycol. For such a solution the concentration of glycol in the hydrocarbon liquid recovered theoretically should not exceed 0.04% by weight.
Advantages:	<ol style="list-style-type: none"> <li>1. Effective at lower pressure differentials since it gives dew-point depressions over and above those obtained by refrigeration alone.</li> <li>2. High recoveries of natural gas condensate possible.</li> <li>3. A compact unit with high salvage value.</li> <li>4. Stabilization of the recovered liquid less expensive since this liquid is colder than that from a comparative low-temperature-separation system.</li> <li>5. For flow rates above 17,000,000 cu. ft., initial cost less than that for a low-temperature-separation unit.</li> </ol>
Disadvantages:	<ol style="list-style-type: none"> <li>1. Higher initial investment than the glycol absorption unit at rates less than 17,000,000 cu. ft.</li> <li>2. Slightly greater operating and maintenance cost than a low-temperature-separation system.</li> <li>3. Return of glycol solution to injection point. The total quantity involved, however, is small.</li> </ol>

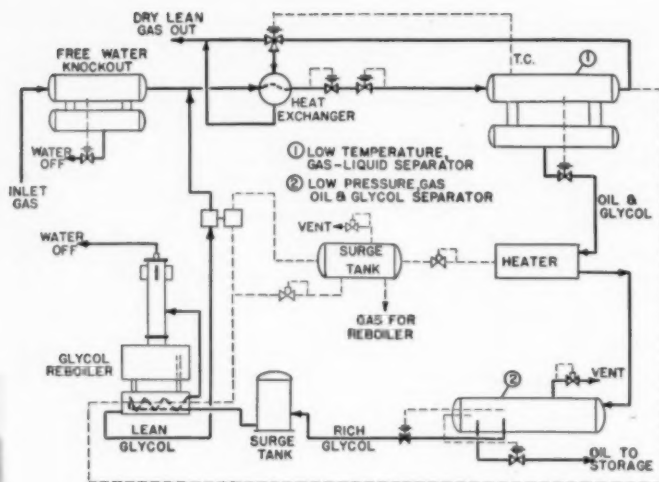


Fig. 8. Flow sheet for a glycol injection system.

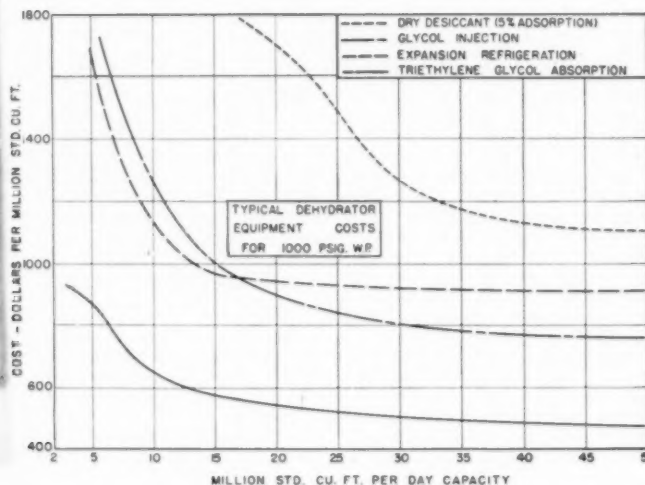


Fig. 9. Relative initial equipment costs for dehydration systems (see Fig. 10) at 1000 lb./sq.in. gage W.P.

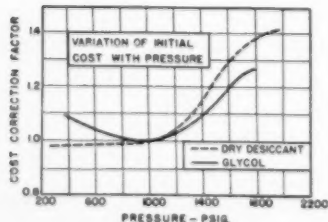


Fig. 10. Variation of initial equipment cost with pressure (see Fig. 9).

unless the process specifications require an effluent moisture content lower than that which can be obtained with glycol dehydration, or where the contact temperatures are too high. In the average application, then, temperature is a predominant factor.

In those applications, however, in which a two-sorber dry desiccant plant is not necessary for continuous service with large gas loads, such as the drying of instrument air and other similar operations, the initial cost is substantially less than shown here since all prices and costs are based on two-sorber systems complete with automatic switching valves, heat exchangers, and the other necessary accessories. Multiple-tower systems using other than two towers have also been used, and of course the costs shown would not apply to these. However, where continuous service is necessary, it has been found that the two-tower system gives very satisfactory service with a lower initial cost than the other multiple systems. The latter are normally used to increase the flexibility of the plant.

The relative typical costs of the dehydrator systems discussed previously are shown in Figure 9 for flow rates from 2,000,000 to 50,000,000 cu. ft. All costs are based on the use of 1050 lb./sq.in. gage W. P. vessels, which are most commonly found in the natural gas industry. It is impossible to obtain a true comparison between these systems for all applications because there are several modifications of the low-temperature and glycol-injection systems to fit the various operating conditions found in the field. In addition, initial cost does not give a true comparison because of the increased condensate revenue obtained with the low-temperature systems. This increased revenue obtained by these systems over those with conventional separation should be figured when comparing both initial and operating costs.

The low-temperature-separation costs apply to the system shown in Figure 5, and the glycol-injection costs apply to the system shown in Figure 8. The costs shown for the triethylene glycol dehydrator and the dry desiccant unit apply to the units shown in Figures 1 and 3, respectively, and are the typical costs for such units complete with all pipings and controls. Skid mounting is normally employed.

These curves illustrate the wide divergence of cost obtained among the four systems and further emphasize the need for the proper evaluation of each system to the individual problem. On the basis of cost alone the triethylene glycol dehydrator would always be the choice of the system desired, and although this system has very wide appli-

all gases except natural gas, where condensate recovery is not a factor, the use of the expansion processes is less economical because of the relatively high cost of these units as compared to the triethylene glycol absorption system. In fact, the use of these expansion systems in the natural gas industry is not economical if compression is required to obtain the high pressures involved. A further analysis of the cost shows that dry desiccant dehydration cannot be justified from the cost standpoint alone.

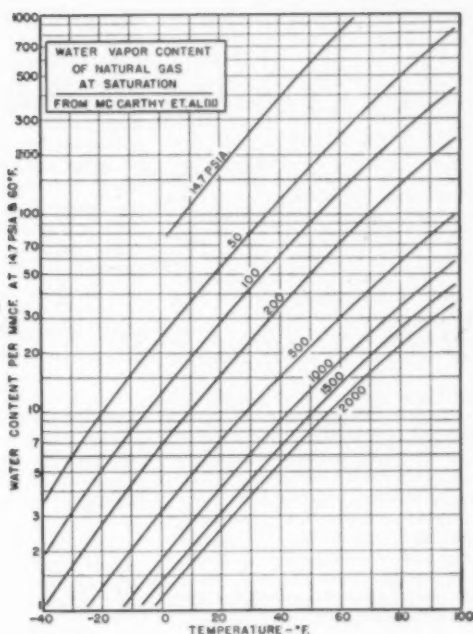
cation and is the cheapest means of dehydration alone, there are some applications in which it does not apply or does not give the optimum payout.

**Pressure Factors.** Figure 10 shows the pressure-correction factors to be applied to the costs in Figure 9, for pressures other than 1000 lb./sq. in. gage. No curves are shown for the expansion-refrigeration or glycol-injection systems because so many variables are present as the pressures are changed in the system that a simple curve cannot be used to correlate the data. For such equipment, however, an increase in the pressure of the low-temperature separator gives a rising cost for the unit, for any such cost is also a function of the pressure upstream from the throttling valve.

With reference to Figure 10, the cost of a dry desiccant unit is not substantially changed in the range of pressure from 500 to 1000 lb. because as the pressure increases, the vessels become not only progressively smaller but also progressively thicker, and in the long run the net change is very small. As the vessels become thicker, heavier valves must be used, and all flanges and other accessories become substantially higher in cost. In other words, the cost jumps sharply from that at 1100 to that at 1500 lb./sq. in. gage and then levels out as the fittings and accessories for the higher pressure range must be supplied.

As shown in Figure 10, the cost of a triethylene glycol dehydration plant goes through a minimum. With reference to Figure 3, this unit consists of all low-pressure equipment except for the absorber proper. As the pressure is increased, the reboiler and still column are slightly smaller because at higher pressures the gas can hold less water in the vapor phase. Therefore, the regeneration load is reduced. At the lower pressures the absorber column must be of a larger diameter in order to maintain the necessary velocities, and even though the shell thickness of the vessel is less, the cost of fabrication is fairly high. This, together with the higher reboiler cost for the lower pressure, gives a higher cost than at 1000 lb. This difference in cost may be illustrated by reference to Figure 11, which is a recent correlation showing the water content of

Fig. 11. Water content of natural gas at saturation.



natural gas as a function of temperature (11). At 80°F. and 1000 lb./sq. in. gage the gas will hold about 34 lb. of water/1,000,000 std. cu.ft. whereas at 500 lb./sq. in. gage the same gas will hold about 58 lb. of water/1,000,000 std. cu.ft. This increases the necessary circulation rate, which gives a larger pump and a correspondingly larger heat load on the reboiler system.

As the pressure on the system is increased, the cost of the absorber goes up, owing to the higher shell thickness, and the cost of the reboiler system goes down. However, the latter system goes down in price more than the absorber increases, which accounts for the minimum in the curve at about 1000-lb. pressure. Of course as the pressure increases above 1000 lb., the cost of the absorber plus accessories becomes a major factor, and the initial cost consequently climbs. Standard triethylene glycol dehydration systems are now available up to 2000 lb./sq. in. gage W.P. On the basis of the information now available, the cost of the systems at higher pressures will level off very much like the dry desiccant units, except at a lower value.

**Operating Cost.** The operating cost, which is a factor along with the initial cost, also varies quite widely among the four systems discussed. Typical costs from field surveys are shown in Table 6. These costs do not include the op-

erational labor and maintenance costs because these figures vary widely among companies and depend to a large degree on the location of the dehydration plant. Most recent dehydration plants are designed for entirely automatic operation and consequently require minimum attention. Therefore, most operators are assigned to other duties along with those on the dehydration facilities. In those instances where the operation is not automatic, such as a dry desiccant plant with manually operated valves, the operating cost of the plant would be higher.

The operating cost of the dry desiccant plant is based on a reasonable desiccant life of two years, which is a good mean average figure, although a number of companies report a substantially longer desiccant life. The life of a desiccant is a function of its degree of saturation during the repeated cycles. If a desiccant is saturated to about 1% capacity each time before being regenerated, it will last for a long period, but, as the percentage of saturation is increased, the desiccant life is proportionately decreased. The lower the desiccant capacity that is used in designing the vessel, the larger such vessels become. The initial cost of the plant therefore increases, and so it is necessary to strike a balance between these costs. On the basis of a large number of investigations it has been found that the use of 5%

TABLE 6.—SUMMARY OF OPERATING COSTS FOR VARIOUS TYPES OF DEHYDRATION

Drying System	Cost—Dollars per MMCF
Triethylene Glycol Absorption ..	\$0.20-0.40 (12)
Dry Desiccant .....	\$0.60-1.20
Glycol Injection .....	\$0.60-1.30
Low Temperature .....	No direct operating expense except labor and routine maintenance.

sorption, for design, on the higher capacity gel-type desiccants results in a decreased cost of drying even though the cost of the initial unit is about 10% more. This saving is realized by the increased life of the desiccant. With the alumina desiccants a design figure of 3 to 5% will give the same minimum total cost. The capacities used for design purposes, of course, are much less than the capacity of the desiccants. It has been found that the use of these figures results in net savings over the use of the usual 7% and 5% adsorption figures for the gel and alumina desiccants, respectively, in many instances.

No comparative cost is shown for the low-temperature dehydration system because it can be seen from the flow sheet that there are no direct expenditures for regeneration equipment and the like in this particular system. However, this does not mean that such a system is the least expensive to operate in the long run since some difficulty may be encountered in operation, particularly when used in borderline cases of application. Consequently, labor costs may be abnormally high. A cost figure for this type of operation is rather illusive, and so no attempt has been made to give a typical figure. However, it should not be more than that shown for the glycol injection system, since the cost of the latter involves the slight cost of replacing and regenerating the glycol.

Table 6 shows that the cost of operating a glycol dehydration system is less than that for any of the others, and this, together with the low initial cost, makes it the ideal system for dehydration from the cost standpoint alone. The cost of this unit may be compared with that for diethylene glycol units and the other types since their costs have been discussed in the literature (5, 15).

### Properties of Gas

In the choice of the dehydration system it is necessary to have data on the ability of the gas to hold water as well as data on the formation of hydrates in natural gas. Both subjects have been widely discussed in the literature, and the author has found that the chart of McCarthy, et al. (11), gives reliable results when compared with the gravimetric analysis of the gas. Many other charts are available, however (1, 12, 14, 18, 20). Hydrate curves are also available for natural gas (1, 6, 7, 8), and these may be used to determine the limitations on the systems.

### Summary

Data have been presented which show the relative costs for the four common dehydration systems. The limitations

and applications of these systems have been summarized in order to facilitate their evaluation.

From the initial- and operating-cost standpoint, triethylene glycol absorption dehydrators were found to be the most economical. However, such a system has limitations which prevent the choice being made from economic considerations alone.

In those natural gas applications where sufficient pressure drop is available between the well and transmission line, the expansion-refrigeration or low-temperature-separation system and/or glycol injection are a logical choice for dehydration if the quantity of additional condensate recovery merits it.

Glycol injection possesses additional flexibility over other low-temperature systems and gives lower exit dew points, together with more liquid recovery, for a given system. At flow rates above 17,000,000 cu. ft. the initial cost is also less.

Triethylene glycol has been found to possess substantial advantage over diethylene glycol as a liquid desiccant, owing primarily to its lower vapor pressure and the greater ease of reconcentration. Dew-point depressions of 55° to 85° F. are normally obtained with this newer system.

### Notation

All references to standard cubic feet are for gases measured at 14.7 lb./sq. in. abs. and 60°F.

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### Discussion

W. W. Bodle (J. F. Pritchard & Co., Kansas City, Mo.): In the expansion-type refrigeration system do you have to take any special precautions or use any special equipment for separating the hydrocarbon oils from the glycol?

John M. Campbell: The separation is simple. A three-phase separator is used which utilizes a baffle and two level controls. Glycol and water are miscible but are mutually immiscible with hydrocarbons. An interphase controller is used to control the level of the glycol-water phase while the hydrocarbon is allowed to flow over a baffle, where it is dumped. The solubility of glycol in condensate is about 0.04% by weight; therefore the cost is low.

W. L. Light (University of Cincinnati, Cincinnati, Ohio): What method or instrument do you use for measuring those low dew points?

John M. Campbell: Dew points are normally measured to only about -30°F. in the natural gas industry since the temperature may be obtained with propane expansion. The Bureau of Mines dew-point tester is normally used. If properly used, this tester gives accurate results although the human error can be large. There are many arguments about its accuracy, but our data (1) show a consistent error not exceeding 2°F. A new automatic tester has been developed which looks good and is now undergoing field tests.

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# BIOLOGICAL TREATMENT OF INDUSTRIAL WASTES\*

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**B**IOLOGICAL oxidation of industrial wastes, although similar to domestic sewage, may present some problems in relation to their concentration, type of materials, and the presence of toxic substances. Primarily, three interrelated factors—food, organisms, and environment—affect biological oxidation.

**Food.** The chemical composition and physical state of subdivision affect the availability of the food. Some organic materials are more readily available than others: sugars are more readily available than lignins, although both are composed of carbon, hydrogen, and oxygen. In general, as the complexity of the organic substances increases, the availability decreases.

The physical state of subdivision of the food affects its availability and the rate of oxidation. Since microorganisms obtain their food by a process of diffusion through the cell membrane, it follows that only diffusible and soluble materials are readily available. Nondiffusible and coarse particles must be converted into soluble materials by exocellular enzymes by a process of hydrolysis before they can diffuse into the cells and be absorbed. Hence, in wastes containing both soluble and insoluble organic materials, the former is oxidized first, whereas the oxidation of the insoluble fraction is controlled by the rate at which it is hydrolyzed. It follows that wastes containing only insoluble particles will be oxidized at a slower rate than wastes containing only soluble materials.

In general, the rate of oxidation is independent of the quantity of organic material (food) present, but when strong wastes are treated the rate of

oxidation may be affected by a deficiency of the oxygen supplied.

The carbon-nitrogen ratio of the organic materials also affects rate of availability. Investigations have shown that one part of nitrogen is required for every 20 parts B.O.D. of the waste to allow oxidation to proceed rapidly.

Phosphorus is essential also for cell nutrition and oxidation of organic material. About one part of phosphorus for each 75 to 100 parts of B.O.D. is required.

**Organisms.** Complex organic materials cannot be oxidized in the absence of microorganisms. Plain aeration in the absence of organisms may result in some coalescence of finely divided material and chemical oxidation of reduced substances such as sulfides, but no biochemical oxidation. In general, the greater the numbers of organisms present the shorter the time required for oxidation. However, there is a relationship between the number of organisms and the food supply. This means that excessive numbers of organisms are of little value if a limited food supply (low concentration of impurities) is present. The oxidation may be accomplished by aggregations of organisms (activated sludge floc) or by bacteria in a dispersed state.

The oxidation of complex organic materials present in sewage or industrial wastes is not carried on expeditiously by a single type of organism. Hence, treatment of industrial wastes by pure cultures of organisms, even though feasible, would not be an efficient process. (There is no comparison between waste oxidation and industrial fermentation or antibiotics production, because in the processes using a single type of organisms, only a specific material is produced, leaving the bulk of the original organic material unoxidized.) Two types of bacteria working in association are better than one type alone, because one of them may utilize the products of the

other and carry the oxidation process further. As the number of types of bacteria increase, the efficiency increases. The introduction of protozoa into wastes containing a great number and different types of bacteria increases the rate of oxidation. This leads to the concept of a biological community or association, and a chain of living forms of organisms. The types of organisms within this living chain vary with the type of waste and the environmental conditions, and a single type of organism may be preponderant in a specific type of waste. Those that fit into a particular chain of reactions and form a necessary link with the preceding or succeeding reactions will survive and predominate, whereas others will be eliminated or reduced in numbers.

The preceding discussion on the effect of types and numbers on oxidation is based upon the premise that a process has been developed and has been in progress in which a successful adaptation or acclimatization of flora and fauna, originally present in the waste or after its artificial introduction, has taken place. If the diversified flora and fauna are lacking, it may be necessary to introduce a "seeding" material, such as domestic sewage or soil suspensions, which contain the diversified organisms.

Acclimatization or adaptation may be brought about by natural selection where certain species in the mixed population find the conditions and food best suited for their development and eventually become the predominant forms, or may be brought about by "training" where certain species when subjected to unfavorable conditions such as toxic materials, may be made to tolerate eventually a higher concentration of toxic substances. Certain varieties in the species of organisms may be more resistant than others or they may be trained to withstand a higher amount of toxic materials by gradually increasing the concentration.

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It is important to bear in mind that such a process of acclimatization, adaptation, training, selection, and mutation has definite limits. It is not possible to treat wastes containing high concentrations of toxic materials, no matter how assiduously attempted. There is an upper concentration of poison that can be tolerated and the maximum concentration that can be tolerated depends on the specific compound. It is also affected by the type and concentration of the non-toxic organic matter present in the waste.

**Environmental Conditions.** The effects of pH values and temperature are well known. The oxidation rates of wastes between pH values 6 and 8 are not materially affected. Frequently, there is a tendency for the pH value of an acid waste to rise, and of an alkaline waste to decrease as a result of treatment by an oxidation process. The natural compensation may be utilized before pH correction is attempted. Mineral acids are not utilized by bacteria under aerobic conditions. Since one of the end products of complete oxidation is carbon dioxide, this gas may affect the pH value considerably, especially in poorly buffered wastes.

The temperature coefficients during deoxygenation of diluted wastes have been carefully worked out. In general, higher temperatures (within limits) speed up the rate of oxidation.

The presence of an ample supply of oxygen is essential for oxidation. Theoretically, maintenance of a trace of oxygen is sufficient, but industrial wastes with a high oxygen demand, require the maintenance of a higher dissolved oxygen level to increase the rate of oxygen diffusion.

**Oxidation Devices.** In general, oxidation devices may be divided into two groups; namely, those utilizing flocculent growths and those utilizing non-flocculent growths. In the first group belong activated sludge, low-rate trickling filters and high-rate filters. In the second category may be included sand filters and the aeration with dispersed growths. The difference between these two groups of treatment devices consists mainly in the relative quantities of sludge produced. In the first group the purification and oxidation occur in flocculent masses of growth, whereas in the second the oxidation is accomplished by dispersed bacterial cells.

### Digestion

The decomposition of organic material brought about by bacterial action under anaerobic conditions is accompanied by the production of intermediate and end products. The inter-

mediate products are primarily organic acids. The volatile acids produced are mainly acetic, butyric, and propionic; under certain conditions valeric acid may be present. The end products are mainly gases, a humus-like residue and salts. The gases consist chiefly of methane, carbon dioxide and water, and under certain conditions, hydrogen. Of the salts formed, the most important are the ammonium carbonates, which play an important role in the buffering of the material.

The main factors affecting the rate of digestion and which are subject to control are seeding, temperature, and reaction.

**Seeding.** Seeding or inoculation of wastes with fully digested residual material is the most important single factor. The digested material or sludge contains the organisms and enzymes needed for rapid digestion, provides a balanced environment for the organisms, and contains materials which counteract the effects of intermediate decomposition products formed during the early stages of digestion. The quantities of end products (gas, etc.) are not influenced by seeding but the rate of production is increased, hence time required is decreased.

**Temperature.** The optimum range for mesophilic digestion is about 85 to 95° F. Lower temperatures increase the time required, whereas higher temperatures in the mesophilic range have little effect.

**Reaction.** Organisms responsible for active and thorough digestion consist of a variety of types. The community of organisms works best in an environment which is about neutral. The optimum pH value for digestion varies with the water supply and types of wastes to be digested. The usual range for various types of organic wastes is from pH 6.5 to 8.0. In some cases reaction adjustment with weak alkalies, preferably lime, is required to maintain an optimum rate of digestion.

**Nutrients.** Industrial wastes which lack sufficient quantities of nitrogen or phosphorus to maintain a definite ratio must be reinforced with nutrients. Experimental results indicate that the carbon-nitrogen-phosphorus ratio for efficient digestion should be about the same as for efficient oxidation.

**Methods of Digestion.** The methods used can be divided into: batch and continuous digestion. In batch digestion concentrated solids are added one or more times a day to the digester, whereas in continuous digesters a weaker liquid is constantly added. The latter method is preferable for larger

volumes containing soluble organic wastes (such as fermentation, antibiotics, sugar, and starch, slaughterhouse wastes) provided the waste is introduced into the tanks in such a manner that it comes into intimate contact with the seed material. So-called upward flow distribution systems have been developed for this purpose.

### Practical Applications

The potentialities, applications, and actual performance of biological treatment processes for the separate treatment of industrial waste on the basis of actual large-scale installations and pilot plant experiences, are briefly discussed. An attempt has been made to answer some specific questions: how are biological treatment processes suitable for the treatment of industrial wastes; what treatment processes have actually been used for the various wastes; have there been novel biological processes developed different from those developed for sewage treatment; and what has been the measure of success. A strict definition of biological processes has been applied, which excludes ponding and lagooning. This paper, based on a literature survey, has no pretensions of being exhaustive. Elimination of waste, salvage, recovery or utilization methods are not included, neither are wastes treated in combination with sewage in municipal treatment plants.

**Antibiotics.** The waste-disposal problem arising from the manufacture of antibiotics is comparatively recent, but one that is assuming increasing importance because of the expansion of the industry and large volumes and concentrations of the waste discharged.

The two best-known separate treatment systems are at the Upjohn Co. plant in Kalamazoo, Mich., and at Lederle Laboratories at Pearl River, N. Y. The Upjohn Co. plant is treating penicillin and streptomycin wastes and the Lederle plant is treating primarily wastes arising from the manufacture of aureomycin. Both plants use trickling filters as the essential feature of biological process.

There are three 100-ft. filters, 6 ft. deep, each provided with a clarifier with 1.5-hr. detention at the Lederle plant (3). The waste is first treated by aeration for 14.5 hr. The final effluent is discharged into the municipal sewer. The B.O.D. reductions at this plant vary from 40 to 80%; low values being obtained in the winter when the load on the filters is also high.

The treatment plant of Upjohn Co. (18) consists of holding tanks with a 10-hr. detention period and provisions for aeration, preliminary sedimentation tanks with 2-hr. detention, and two 90-ft. diam. trickling filters 6 ft. deep. The loading on the filters is 1500 lb. B.O.D./acre ft./day. The filters can be operated either in series or in parallel. When operated in series the filters can be alternated, but there is no provision for intermediate sedimentation. Recirculation of effluent or dilution with cooling water is practiced. The effluent from the filters is settled and chlorinated. The

sludge is digested and disposed of by drying on open sand beds. An over-all B.O.D. reduction of 97% is obtained.

At the antibiotic production plant of Heyden Chemical Corp. in Princeton, N. J., a considerable amount of experimental work on pilot plant scale was done for the treatment of penicillin wastes (30). Biological filtration through coarse and fine-grained medium (sand), in deep and shallow filters, with and without recirculation and aeration was studied. It was concluded that all methods could be used. Selection of the method depends upon economics, operating difficulties and the degree of treatment required. Several combinations of treatments were capable of removing 99% of the B.O.D., producing an effluent with 30 p.p.m. of B.O.D. Combinations of units that could be employed were (a) Two shallow recirculated filters in series, followed by a deep filter, (b) Three-stage shallow recirculated filters, (c) Two-stage deep filters, (d) Two-stage shallow filters followed by sand filters, (e) Aeration followed by deep filters. The first three combinations offer the lowest operating costs and the most trouble-free operation. Aeration has the advantage of low first cost, but the disadvantage of severe foaming, high-power consumption and large quantities of sludge produced.

**Beet Sugar.** The treatment of beet sugar wastes by biological filtration was tried in England on a large scale (36). The experimental plant consisted of Dortmund tanks and two 25-ft. diam. 6-ft. deep filters. The effluent from the filters was settled in Dortmund-type secondary settling tanks. The waste treated consisted of diffusion and pulp press water. A 90% purification was effected. It was found necessary to dilute the waste to a solution equivalent to 0.1% sucrose by recirculation or with the use of transport and wash waters. The diluted waste could be filtered at the rate of 100-150 gal./cu.yd. (day).

The treatment of whey and pulp water on a small scale was reported by Levine (24). The settled whey and pulp water was applied to filters 3 ft. square and 9 ft. deep and a shallow washable cinder filter 4 x 6 ft. in area and 3 ft. deep with the effluent applied to a filter 3 ft. sq. and 6 ft. deep. It was concluded that pulp water could be treated by trickling filters after removal of suspended solids by sedimentation.

**Canning Wastes.** At Albion, N. Y., pea, green bean, and tomato wastes are treated on standard high-rate filters with 97% B.O.D. reduction (39).

Digestion of tomato and pumpkin waste was reported by Canham and Bloodgood (6). The digester used was 6 ft. wide 12 ft. long and 7 ft. deep. Contents were agitated with a horizontal paddle, the overflow settled and the sludge returned to the digester. Above 72° F. and with a 10-day digestion period, an effluent with less than 200 p.p.m. B.O.D. could be produced from tomato waste with an original average B.O.D. of 590 p.p.m. without the production of offensive odors.

**Dairy Wastes.** A full-size high rate recirculating filter at Perrinton, Mich., for milk waste treatment gave 90% B.O.D. reduction, according to Eldridge (11). The filter was 36 ft. in diam. 6 ft. deep. The filters were operating below design capacity.

A recirculating trickling filter (60 ft. in diam., 8 ft. deep) was installed for Carnation Milk Co. at Cambridge Springs, Pa. (22).

Hatch and Bass (17) reported the operation of three milk waste treatment plants. At the Pet Milk Co. plant in Coldwater, Ohio, raw waste with 1290 p.p.m. B.O.D., after receiving preliminary settling, is diluted with pan water or effluent before being applied to the filter. An over-all removal of 98.3% B.O.D. was obtained.

At Glen Karn, Ohio, Kraft Phoenix Cheese Corp. installed a Guggenheim process. Lime, iron salts, and return sludge are added to the waste and aerated for four hours. B.O.D. of the raw waste (755 p.p.m.) was reduced 76%.

At New Bremen, Ohio, White Mountain Creamery Co., the waste is treated by the activated sludge process with a design aeration period of 24 hr. and based on actual flows of 48 hr. The raw wastes have a B.O.D. of 1245 p.p.m. and an over-all plant efficiency of 98.9% was obtained. The sludge is reported to be bulky with an index of 400, with an air input of 1.2 cu.ft./gal. of waste treated. It was concluded that milk waste can be treated by the activated sludge process with excellent results.

Another activated sludge plant for the treatment of dairy waste has been operated for H. W. Walker Co. at Somerset, Pa., with similar results (29).

An aeration process for Dean Milk Co. at Huntley, Ill., was developed (16). The waste produced a floc upon aeration which was returned to the aeration unit. This was not the original intention. B.O.D. reduction varied from 72 to 78% and frequent upsets occurred.

Waste treatment facilities at Belle Center Creamery and Cheese Co., consist of aeration of the waste with return activated sludge. The treatment plant gave satisfactory results with a B.O.D. in the effluent of 19 p.p.m. (31).

Eldridge (12) and Mallory (26) describe the operation of plant constructed for Mead Johnson dairy plant at Zeeland, Mich. The treatment consists of digestion of whey and curd washings, followed by sedimentation, aeration, and final settling for the effluent from the digester and the weaker wastes.

Large-scale experiments made by the Water Pollution Research Board (44) on the treatment of milk and whey washings by the activated sludge process produced effluents of not as good quality as effluents obtained by the treatment of similar liquids by double filtration. Operating difficulties were encountered with bulking and rising sludges.

From similar large-scale experimental units with double filtration with periodic changes in the order of filters, it was concluded that milk and whey washings and mixtures of the two could be purified when settled and the diluted liquor, with a B.O.D. of 200-300 p.p.m., applied to alternating double filters at the rate of 160 gal./cu.yd. (day). Milk washings alone could be applied at the rate of 240 gal./cu.yd. (day). Shock loads caused only temporary deterioration in the quality of the effluent.

Wilson (45) reports the construction of high-rate filters operated in series with multiple recirculation for the Central Kansas Cooperative Creamery Association at Hillsboro, Kan. The primary filter was designed to receive a load of 4.4 lb. B.O.D./cu.yd. and the secondary filters 1.2 lb. No operating results were reported.

Two-stage high-rate filters with recirculation are also installed for the Detroit Creamery Co. at Ovid, Mich. (32).

**Brewery, Distillery, and Yeast Wastes.** Operation of the waste treatment plant of the Gulf Brewing Co. at Houston, Tex., is

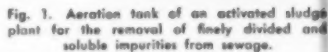


Fig. 1. Aeration tank of an activated sludge plant for the removal of finely divided and soluble impurities from sewage.

described by Tollman (42). The main treatment unit consists of a settling tank, two trickling filters in series, 100 ft. diam. and 6.5 ft. deep. An over-all efficiency of 83.7% on suspended solids and 96.5% on B.O.D. is obtained.

At the Lucky Lager Brewing Co. in Azusa, Calif., the treatment for washings and drainage water consists of fine screens, primary clarifier and two biofilters, 60 ft. diam. and 3 ft. deep, designed for a load of 1.6 lb. B.O.D./cu.yd. with recirculation of the effluent. An over-all B.O.D. reduction of 88% is obtained. The sludge is digested and dried on open drying beds (40).

Buswell (5) reported on the basis of pilot plant experiments a treatment system for distillery slop consisting of digestion followed by trickling filters. The B.O.D. of the raw slop was reduced from 15,000 p.p.m. to 1500-2000 p.p.m. by digestion. The effluent from the digester was applied to a filter at the rate of 250,000 gal./acre (day).

The treatment for Monticello Distillery at Cedarhurst, Md., consists of a primary clarifier, high-rate trickling filter, secondary clarifier, digester, and sludge drying beds. Sludge loading on the filter is 0.75 lb. B.O.D./cu.yd. The volumetric dosage is eight m.g.a.d. including the recirculation which is four times the waste volume. A B.O.D. reduction of 99.9% is expected (9).

Buswell (4) presents data for the digestion of four fermentation waste plants. These comprise the yeast waste treatment plants at Pekin, Ill., and Crystal Lake, Ill., the butanol fermentation waste plant at Peoria, Ill., and distillery waste plant at Carthage, Ohio. The loadings on the digesters in these plants were between 0.1 to 0.14 lb. B.O.D./cu.ft. (day). B.O.D. removals varied from 70 to 90% and the gas yields from 4.25 to 11 cu.ft. per lb. of solids.

Extensive large-scale experimental treatment of yeast wastes was reported by Rudolfs and Trubnick (38). The treatment consisted of digestion, sedimentation, and

biological filtration. The two digesters were operated on the basis of continuous flow either in series or parallel. The raw waste was fed at the bottom through a nozzle equipped with a splash plate which permitted the waste to pass through the sludge blanket upward to the effluent. It was concluded that a two-stage digestion produced greater B.O.D. reduction per unit B.O.D. loading than one stage operation. Loadings of 0.13 lb. of B.O.D./cu.yd./day gave B.O.D. reduction of 85% and a gas yield of 7.5 cu.ft./lb. of volatile solids added. Definite minimum quantities of sludge are required in the digester, but excessive quantities are detrimental to good purification. On account of low suspended solids content of the waste sludge accumulation was slow. The original seed obtained from a sewage plant was viable for five years, no reseed being required. The sludge was capable of shock loads without retardation of purification. Proper mixing of the raw waste with the sludge allowed higher loadings than quiescent digestion.

Experiments with the treatment of raw wash water and spent nutrients and digested liquors in various combination were made with trickling filters (15 ft. diam. and 4 ft. deep) equipped with rotary arms. The filters were operated in series with recirculation. Irrespective of the nature of applied waste the filters removed 50% of the B.O.D. applied. Loadings of 11,000 to 12,000 lb. of B.O.D./acre ft./day could be applied without material deterioration of purification. The quality of the effluent depended upon the B.O.D. of the raw waste and recirculation was of value as a means of diluting the concentrated waste.

**Packing-House Wastes.** Levine et al (25) treated packing-house waste at Mason City, Ia., by the activated sludge process, but troubles were encountered from sludge rising and foaming; a B.O.D. reduction of 85% was obtained. By double filtration first on a declogable washable filter then applying the settled effluent on the secondary filter, a high degree of purification was obtained with well-nitrified effluent. Semi-pilot scale experiments were carried out on the digestion of primary and secondary sludges produced from the treatment of packing-house wastes.

The treatment of Kuhner Packing Co. wastes at Muncie, Ind., by the activated sludge process is reported by Milling and Poole (28). Preaeration for 30-60 min. in the presence of activated sludge is followed by settling and aeration with activated sludge from 11 to 22 hr. Air consumption was 4.25 cu.ft./gal. of waste treated. An

over-all B.O.D. reduction of 98.8% was obtained.

Armour Co. plant at West Fargo, N. D., treats its waste by two- or three-stage high-rate filters. The primary filters equipped with air and water wash are operated at 5000 to 6000 lb. of B.O.D./acre ft./day. A 95% B.O.D. is removed by the plant from a raw waste with 1000 p.p.m. B.O.D. (20).

Eldridge (13) reports the results of the operation of a trickling filter treating slaughterhouse and meat-packing waste. The waste is treated in a septic tank and the effluent by recirculated trickling filter with an over-all 98% B.O.D. reduction B.O.D. loading was 0.65 lb./cu.yd. and a recirculation ratio of 4.7:1 was used.

Aerofiltration of chemically treated packing-house waste at a small packing-house is reported by Klassen and Hasfurth (23). At a loading of 4050 lb./acre ft. the over-all reduction was 94.5%.

Activated sludge treatment of rendering plant wastes was reported by Uhlmann (43). The treatment units consisted of primary settling, aeration, final sedimentation, sand filters, and lagoons. Aeration period was 13 to 14 hr. with an air input of 2-3 cu.ft./gal. The B.O.D. of the raw waste was reduced from 450-695 p.p.m. to 7-20 in the secondary clarifier effluent.

**Paper and Pulp Waste.** Southgate (41) reports on a pilot plant filter built at a paper mill and operated in series.

Gehm and Morgan (14) and Bloodgood (1) report on the construction of a pilot scale digestion tank for the treatment of strawboard wastes. The digester is of unusual design in that the contents are continuously agitated, overflow liquor settled and the sludge returned to the digester similar to the activated sludge system. The removal of B.O.D. amounted to 95.5% but a number of operating difficulties were encountered. The digested sludge became bulky and would not settle in the settling tanks.

The biological treatment of waste sulfite liquor by the activated sludge process on a large scale has not been undertaken because of the low level of loadings and difficulties indicated from the laboratory scale work according to Holderby and Wiley (19).

Pilot plant scale biological filtration of waste sulfite liquor, however, was undertaken. Results indicate that this waste can be treated on a trickling filter with B.O.D. removals of 65-75%. Operating difficulties make the attainment of this efficiency difficult. To overcome the clogging difficulty rock of not less than 4-in. diam. is recom-

mended. Seasonal temperature changes affected the efficiency. High acidities lead to the production of a film high in molds and yeast and deficient in a balanced flora. Periodic unloading resulted in loss of efficiency. Approximately eight acres of filter area 6 ft. deep would be required to handle the waste from 100-ton daily pulp production. The cost of treatment would increase further by the necessity of nitrogen and phosphorus additions. High recirculation rates would tend to increase the cost further. Contact aeration was able to handle much heavier loadings than either activated sludge or trickling filters with B.O.D. removals of 70-75%.

Following laboratory and pilot plant experiments for the treatment of deinking wastes by the activated sludge process, a full-scale demonstration plant was constructed at one of the six cooperating mills in Plainfield, Mich. (34). The units consist of primary settling, aeration, secondary settling, sludge concentration tanks, and sludge lagoons. The design of the plant is on the basis of a flow of 0.5 m.g.d. to the primary and 0.16 to 0.25 m.g.d. to the secondary units.

**Phenolic and Formaldehyde Wastes.** At the Dow Chemical Co. in Midland, Mich. (15, 35) phenolic wastes have been successfully treated by biological processes for a number of years. Strong phenolic wastes with a phenol content of 700 p.p.m. (1.5 m.g.d.) is settled and mixed with weak waste containing 1-5 p.p.m. phenol (13.5-23.5 m.g.d.). The mixture is neutralized, settled and treated by trickling filters followed by activated sludge. The effluent is stored in ponds (38 acres). The treatment plant with the exclusion of the effluent pond removed 76 to 92% of the phenol and an over-all removal of 94.6 to 99.3 including the ponds. The filters were able to stand sudden changes of pH and "shock" toxic compounds with temporary drop in efficiency.

A successful biological treatment for wastes containing formaldehyde, resin oil, phenols, organic acids and pentaerythritol was developed by Hercules Powder Co. (10). After elimination and reuse of some of the wastes the formaldehyde concentration was reduced to an average of 1300 p.p.m. which was equivalent to about 600 lb./day of B.O.D. and the total B.O.D. was 675 lb./day. The filter was designed for a loading of 2.8 lb. B.O.D./cu.yd. High recirculation ratios were used, reducing the concentration of formaldehyde applied to the filter to 200 p.p.m. An over-all effi-



Fig. 2. A trickling filter-type plant with settling tank, trickling filter and sludge digestion tank.



Fig. 3. Top of sludge digestion tanks for anaerobic digestion of sewage sludge.

ciency of 76% was obtained on the basis of formaldehyde.

**Textile and Wool Dyeing Wastes.** Treatment of cotton printing and finishing wastes on pilot plant scale was reported by Coburn (7) consisting of equalization, chemical precipitation, and high-rate recirculated trickling filters. B.O.D. reduction of 60% was obtained at a 14 m.g.d. rate of application of raw waste. As a result of these studies a high rate trickling filter process was recommended.

The treatment of cotton finishing wastes by sedimentation and trickling filters was reported by Bogren (2). The settled waste is applied to a filter 10 ft. deep with fixed nozzles at a loading of 0.15 lb. B.O.D./cu.yd. The effluent is treated further on fine cinder filters. An over-all B.O.D. removal of 96% is obtained with a B.O.D. in the raw waste of 280 p.p.m. A pilot high-rate recirculated filter gave 60-70% B.O.D. reduction.

Viscose rayon manufacturing wastes are treated at Front Royal, Va. (37) by recirculated filters. B.O.D. of raw waste is 300 p.p.m. The load on the filter is 300 lb./acre ft. B.O.D. removal of 90% was obtained. After the operation of the filter was upset by the discharge of acid waste, the efficiency was brought back to normal again and even increased to 95-100% removal with a loading of 500 lb. B.O.D./acre ft. Further work showed that when enough acid waste was added to the sulfite containing waste to bring the pH value to 8.0 the filter could take 1050 lb. of B.O.D./acre ft. and remove all of it.

McCarthy (27) concluded from the operation of experimental filters that wool-dyeing wastes could be treated satisfactorily at loadings at least as high as those employed for sanitary sewage.

**Gum Wastes.** A biological treatment plant was constructed for the treatment of gum wastes consisting of digestion followed by settling tank, recirculated trickling filter, and sand filters. An over-all B.O.D. reduction of 90% was obtained (33).

### Comment

A census of construction of waste-treatment plants conducted in 1950 by Cohn (8) showed that 375 waste-treatment plants were either under construction or had been completed. Of these, 26 plants employed biological methods. The total number of plants employing biological treatment processes in existence in this country must be considerable. This review covers only a small cross section of the biological waste-treatment plants in existence. This is partly due to the fact that not all the plants have been described in the literature and partly to incomplete coverage. It is recognized that there are certain limitations to the generalization in this review.

Certain facts however stand out. Biological methods of treatment are suitable for a variety of wastes. Construction of treatment plants for various types of waste after extensive laboratory and pilot plant experimental work, together with operation data from actual installations is convincing evidence of their efficacy. It is not the contention that

all wastes can or should be biologically treated. There are a number of them, such as pickling and plating wastes, for which biological treatment methods would be useless. There are still others for which local conditions do not warrant the degree of treatment obtainable by biological methods, but wherever a high degree of treatment is required for which physical and chemical methods are insufficient, biological methods are available. The following wastes have been treated by biological processes: antibiotic, beet sugar, canning, dairy fermentation, packing-house, deinking and strawboard, phenolic, formaldehyde, and textile wastes. Still others such as waste sulfite liquor and white water can be treated biologically except for economic considerations.

Specific methods of biological treatment have been adapted from the treatment of sanitary sewage. No radical departures have been made from the sewage-treatment practice. The three methods most widely used for the treatment of liquid wastes are biological filtration, activated sludge, and digestion. Both conventional and high-rate filters have been employed with the preference for high-rate filters. Trickling filters have generally been preferred over the activated sludge process, because of their ability to withstand shock as well as ease and lower cost of operation. In several instances bulking, rising, and foaming problems have created considerable operating problems with the activated sludge process. The digestion of liquid wastes as distinguished from the digestion of sludges produced by the sedimentation of suspended solids, originally present in the waste, or produced as the result of biological treatment, has offered a novel departure and an economical method in comparison with the more expensive oxidation devices. Proper distribution and mixing of the raw waste with the seed sludge has offered problems not encountered to the same extent in the digestion of sewage sludge which have been partially solved by introducing the waste from the bottom of the tank and allowing it to pass slowly upward through the sludge zone or by agitation of the tank contents. The sludge escaping from the digester in either case should be captured and returned to the digester in order not to deplete the sludge in the digester which accumulates only slowly when treating wastes containing comparatively small quantities of suspended matter. The effluent from the digester has been successfully treated by biological filtration whenever a higher degree of treatment is required than can be obtained by digestion alone.

Certain principles of equalization, neutralization, and supplementation with

sources of nitrogen and phosphorus wherever necessary, have been recognized for the successful treatment of wastes by biological methods. Equalization serves the purpose of both blending the wastes and uniform application of the wastes to the treatment units. Dilution of strong wastes by recirculation of effluent or with water when applied directly on oxidation devices seems to be necessary.

It is promising to note that wastes containing certain inhibiting compounds such as phenols and formaldehydes are treated successfully by biological processes under carefully controlled conditions. It is also encouraging that, as new wastes are produced such as those derived from the manufacture of antibiotics and gum wastes, biological methods can be adapted for their treatment after laboratory research.

### Conclusions

A review of the theory and published information regarding actual installations and pilot plant experiences of biological processes for the treatment of industrial wastes shows to what extent and with what success such methods have been used. Treatment may be accomplished under anaerobic or aerobic conditions, or by utilizing a combination of these two procedures. Theoretically, biological treatment is not only feasible but is also similar for all types of organic wastes.

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## Discussion

**Anonymous:** Have you any information as to how, costwise, the biological treatment of an antibiotic waste by penicillin would compare with perhaps today's more common method, involving evaporation, filtration, and final incineration disposal of the waste for a plant of a fairly decent size?

**W. Rudolfs:** Cost estimates for full-scale plants, say three or four plants, showed that aside from the nuisance factor created by evaporation, the cost of biological treatment is less. This is

particularly true, because after the material is evaporated there is still the condensate which contains a good deal of material to be oxidized. The B.O.D. of the condenser water from the penicillin evaporation plants runs around 1000 to 1200 p.p.m., or about five or six times stronger than sewage, which cannot be discharged without further treatment.

**F. Mohlman** (Sanitary District of Chicago, 910 S. Michigan Ave., Chicago, Ill.): I'm glad Dr. Rudolfs brought out the biological aspects of this problem because we might not realize the differentiation between physical methods and biological methods. Dr. Rudolfs in speaking of biological methods refers to complete treatment in which the B.O.D. reduction is around 90 to 95%; this degree of treatment is necessary in many cases and biological methods are the only way to produce such results. Chemical methods, or separation methods, were originally developed to separate solids from liquids and they are the Sven Peterson, the Gibbs, the Buckley-Dunton: those processes are effective in separating solids and with the addition of chemicals performance is improved. There would be no biological effect to add to the physical effect. In such cases 60 to 70% reduction of B.O.D. is the maximum to be expected, which would not be satisfactory for sewage. Therefore, it is extending those sedimentation processes beyond their possibilities to say that they would be suitable for all sewage processes. The same thing applies to industrial wastes. There are many industrial wastes in which the problem is to eliminate the B.O.D. or the oxygen requirement of the liquid waste in which the suspended matter is very low. Industrial wastes which are not amenable to physical treatment, must be subjected to biological treatment. Wastes containing large amounts of suspended solids and with low B.O.D. values may be submitted to flotation, which may be cheaper than the biological treatment. For higher degrees of treatment the possibility and applicability of biological methods should be considered and studied, and leave other methods to industrial waste from which suspended matter must be removed. Even in such cases, if it is sewage, various cost items necessary and the effectiveness of removing solids from industrial waste must be seriously considered.

**B. P. Martinez** (U. S. Bureau of Mines, College Park, Md.): Dr. Rudolfs stressed the importance of keeping the carbon, nitrogen, phosphorus ratio intact and he later added a statement that

the nitrogen and the phosphorus may be used to supplement other materials. Should that nitrogen and phosphorus be organic or may it be inorganic, and may I have some suggestions on what type of organic supplement should be used?

**W. Rudolfs:** Ammonium phosphates are mostly used where both nitrogen and phosphorus are lacking as nutrient materials. Ammonium sulfate can be used, but the difficulty arises with gasification in anaerobic decomposition when hydrogen sulfide is produced, which is corrosive.

**B. P. Martinez:** The Meyerhof cycle brings out the importance of the phosphates as a side branch of the sugar molecule in muscle metabolism—transfer of food into energy. Does that complex cycle apply to the life cycle of the bacteria we are using in biological oxidation?

**W. Rudolfs:** Phosphorus is essential for biological growth. Whether it acts in the same way as it does in the muscles of the human body, I'm not prepared to say. Nobody knows. But phosphorus is essential though not so essential as nitrogen. Phosphates are needed, and wherever organic wastes do not contain any phosphorus small quantities must be added in a soluble form.

**H. B. Caldwell** (Swenson Evaporator Co., New York, N. Y.): Dr. Rudolfs spoke of the treatment of sulfite liquor from presumably calcium base sulfite pulp mills. It is not difficult to evaporate such a solution, and burn it in a waste heat boiler, and get some power from it, except for the presence of calcium sulfate and perhaps calcium sulfite which rapidly scales the heating surface of evaporators. Is it possible to treat biologically such liquor so as to solubilize the calcium compounds and thus make evaporation of it a simple step?

**W. Rudolfs:** As I understand it, you want the bugs to work on the calcium; it would be very hard.

**H. B. Caldwell:** Can strongly alkaline material be biologically treated?

**W. Rudolfs:** If the pH is not too high; if a material has a pH value of say 11, oxidation or digestion is extraordinarily slow and speeds up, if and when more carbon dioxide or organic acids are formed. It is practically impossible economically—not theoretically—to subject strong alkali or strongly alkaline or acid waste materials to biological processes without neutralization.

(Presented at Forty-fourth Annual Meeting, Atlantic City, N. J.)

# THE MEASUREMENT OF FLUIDIZATION QUALITY

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An instrument has been described for evaluating the quality of fluidization based upon the measurement of the magnitude and frequency of pressure-drop fluctuations across a section of a fluidized bed. The pressure fluctuations were measured by recording the strain produced in a metal diaphragm by the pressure difference existing across the section of bed.

The quality meter has been tested on fluidized beds of glass beads under varying conditions of bead size, initial bed height, column diameter and per cent bed expansion.

THE development of fluidization techniques in the chemical industry has progressed rapidly within the last ten years. Such characteristics as ease of handling, uniform temperature distribution and high rates of mixing possessed by fluidized beds have contributed to their utilization in many processes. Applications include the cracking of petroleum, hydrocarbon synthesis, gasification of coal, reduction of metallic ores and many others.

In many respects fluidization has developed faster as an art than as a science. While many fluidization units have been built and operated, a complete understanding of the fundamental factors governing the performance of such units has been, in general, lacking. One reason for this has been the difficulty in giving a quantitative significance to the quality or uniformity of fluidization. In most cases it has been necessary to describe bed behavior in terms of various degrees of so-called "good" or "bad" fluidization based on visual observations.

Recently Morse and Ballou (3) have described a meter for measuring the uniformity of fluidization in terms of changes in bed density by electrical conductance measurements within the bed. Gerald (1) has given a brief description of an apparatus for measuring fluidization quality by the measurement of the effects of particle impacts on a diaphragm inserted in the bed, detected by the piezoelectric properties of a crystal.

Morse and Ballou (3) have mentioned certain limitations for their instrument, namely, that the results may vary somewhat with materials tested, and that highly conductive materials cannot be tested. It has also been pointed out that Gerald's crystal technique records the derivative of impact pressure with respect to time rather than the absolute value of pressure. In addition, both of these methods require that the sensing element be located within the bed, causing interruptions to flow.

The present work has been directed towards the development of a meter which can be used external to the bed and which will circumvent other limitations of the earlier meters. To evaluate the performance of the meter the effects of certain variables, believed to influence the quality of fluidization, were investigated in beds of glass beads.

## Flow in the Fluidized Bed

The behavior of a fluidized bed under different conditions of flow has been discussed in detail by many investigators (2-5). In general, a bed may be described as operating under conditions of channeling, slugging or good fluidization. Under conditions of channeling, a fluid may pass through a bed of solid particles by way of a relatively few open channels with only slight disturbance of the solid particles. When slugging occurs the particles tend to agglomerate

and are lifted by fluid bubbles which increase in size as they rise until they may cover the entire cross section of the bed. The resultant slugs eventually decompose as the solid particles fall away from the bubble. Such action gives rise to a high degree of mixing but very uneven fluid velocity distribution. With good fluidization the fluid rises uniformly through the bed and the particles are distributed rather evenly in the fluid stream and are free to circulate more or less at random. All degrees of these behaviors may occur, and more than one type of flow may exist simultaneously in different parts of the same bed.

While, in general, good quality fluidization is often desirable, it should be noted that optimum operation of a fluidized bed may not necessarily correspond to maximum quality or uniformity. As pointed out by Morse and Ballou (3) the most effective operation usually involves a compromise between uniformity and mixing for a given system. The point of compromise will depend upon the characteristics of the system being considered and the relative importance placed upon uniformity and mixing.

It has been observed that the type of flow within a given section of a bed may be expressed in terms of the behavior of the pressure drop across the section. In the case of channeling, the pressure drop, as measured by a liquid manometer, is relatively constant with small or no detectable fluctuations. When slugging occurs, wide fluctuations in pressure drop may be observed. As the approach to high quality fluidization is made, the fluctuations decrease in magnitude and increase in frequency. With good fluidization the fluctuations are small and rapid.

A record of this behavior has been used as the basis of a method for determining the quality of fluidization in at least a semiquantitative manner.

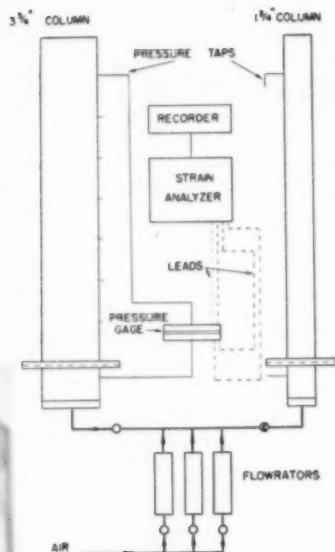


Fig. 1. Sketch of apparatus.

### Apparatus

It was found that no commercial pressure-recording device was available for the conditions required for the quality meter. The measuring element not only had to measure and record the pressure drop but also to measure the fluctuations in pressure drop which in many cases were very small and very rapid. In addition, the record of the pressure fluctuations had to be of such a form that it could be interpreted in terms of fluidization in more than merely a qualitative manner. It was, therefore, necessary to construct a meter having these characteristics.

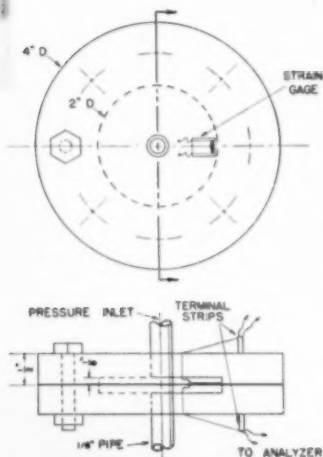


Fig. 2. Details of pressure gage.

The sensing element subjected to the pressure changes consisted of a thin flat metallic diaphragm to which wire strain gages were attached (Fig. 2). The diaphragm was made from aluminum sheet having a thickness of 0.017 in. It was found that the thickness was rather critical. Use of much thicker diaphragms increased the mass of the element and decreased the sensitivity. Use of thinner diaphragms resulted in warping which altered the linear relation between loading and strain. Aluminum was chosen because of its low modulus of elasticity and subsequent significant deflection to pressure change.

The diaphragm was held between the faces of two brass plates 4 in. in diam. The faces of the plates were recessed to a depth of  $\frac{3}{8}$  in. to allow for diaphragm deflection, the recessions being 2 in. in diam. Wire strain gages (Baldwin Locomotive Works, 120 ohms, gage factor  $1.76 \pm 2\%$ ), were bonded to each side of the diaphragm. These were placed close to the edge of the recessed section in order to be subjected to the maximum strain which occurred at the fixed edge of the diaphragm. The strain-gage leads were carried through small holes drilled through the plates to a terminal strip bolted on each side of the housing. These holes were later sealed to prevent leakage. On the terminal strip a 2.2 megohm resistor was provided for calibration purposes. The output from the strain gages was amplified and the resistance circuit completed by means of a Brush Strain Analyzer, connected to the terminal strips by shielded grounded leads. The analyzer is a self-contained a.c. Wheatstone bridge, voltage amplifier, discriminator, and d.c. power amplifier designed specifically for use with wire strain gages. A matched direct inking Brush magnetic oscillograph was coupled to the analyzer for recording the strain-gage output.

Pressure taps on either side of the diaphragm were connected across the desired section of the bed. Since the magnitude of the pressure drops encountered was small, it was found convenient to connect the instrument across the entire bed. In order to keep the capacity of the instrument low and to minimize dampening in the lines, the pressure connections were made of  $\frac{1}{4}$ -in. tubing and made as short as possible.

The fluidized beds were contained in one of two Lucite columns having I.D. of  $1\frac{1}{4}$  in. and  $3\frac{3}{4}$  in. Pressure taps were provided at intervals along the columns. Air was supplied to the columns by a Roots-Connorsville blower and the flow of air measured by calibrated flowmeters covering the desired range. (Fig. 1.)

The glass beads used in this work were supported in the columns by fine bronze screens held between Lucite flanges. Preliminary work indicated that the screen introduced no measurable resistance for the air flows encountered. Characteristics of the beads used are given in Table 1.

The instrument was calibrated for pressure drop by static loading with the aid of a liquid manometer. A linear relation

between pressure drop and pen deflection was found.

### Experimental Procedure

To evaluate the effectiveness of the quality meter it was desirable to test the meter on different bed behaviors. Runs were consequently made at varying flow rates and initial bed heights using several different bead sizes and two column sizes.

Prior to making a run, the column was treated with an antistatic compound to prevent the build-up of electrostatic charges. A weighed quantity of beads of the desired size was placed in the column and fluidized for a few minutes with air. The bed was then allowed to settle by slowly reducing the air flow and the resulting settled bed height, designated as  $H_s$ , was measured and recorded.

The analyzer was turned on and allowed to warm up. The recorder was then started and the analyzer balanced. The calibrating resistance circuit was completed and the gain on the analyzer adjusted to give the desired pen deflection. The circuit was then opened and the meter connected to the bed.

An initial air flow was established just sufficient in most cases to fluidize the bed. Pressure-drop records were taken with chart speeds of 1 cm./sec. and 5 cm./sec. Successive readings were taken at increased air flows until the bed level was near the top of the column.

As a check on the drift of the instrument, the point of zero pressure drop was noted after each run.

### Results

Records from three runs at chart speeds of 5 cm./sec. have been reproduced in Figure 3 to illustrate the difference in various degrees of fluidization quality. The vertical axis indicates the pressure drop and the horizontal axis represents time. For the diaphragm used in this work, the range of pressure drop varied from 0 lb./sq.in. to 0.61 lb./sq.in.

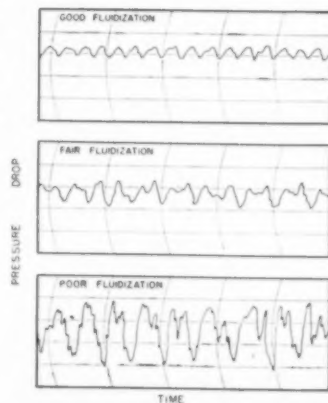


Fig. 3. Typical chart records.

TABLE 1.—CHARACTERISTICS OF GLASS BEADS

Nominal Size	Average Diameter (In.)	Specific Gravity
6	0.028	2.55
9	0.019	2.55
10.4	0.011	2.55

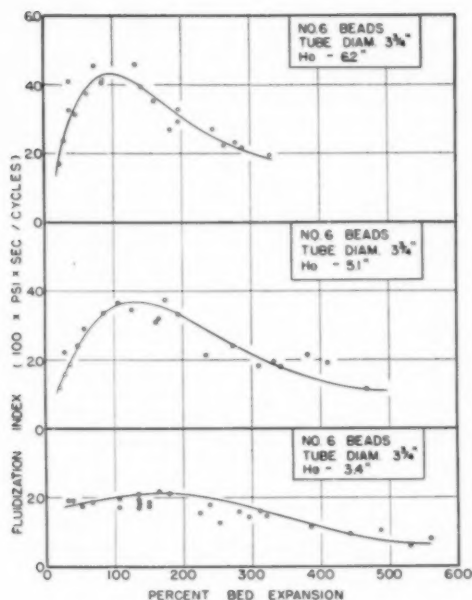


Fig. 4. Fluidization index vs. per cent bed expansion.

The upper chart in Figure 3 represents the record of pressure fluctuations across a bed in which good fluidization was obtained, based on visual observations. Air distribution was uniform and no large air bubbles were present. In the run corresponding to the second chart some tendency towards slugging was evident. Small bubbles were observed to percolate through the bed. The lower chart represents violent slugging in which the air bubbles completely covered the tube cross section and the bed level fluctuated widely.

It can be observed from the chart records that the quality is a function of the magnitude of the pressure-drop fluctuations and also their frequency. This is in accordance with the observations of Morse and Ballou (3) who obtained records which were similar in form. In order to give a numerical value to the fluidization quality these investigators proposed a uniformity index defined as the per cent deviation in bed density divided by the frequency of density fluctuations, these quantities being the variables measured in their work.

In the present work, the quality was expressed by a somewhat similar index, defined as the average pressure-drop deviation divided by the frequency of pressure-drop fluctuations. This value

was multiplied by 100 to give a more convenient magnitude to the index. For fluidized beds the index has a value of zero for perfect fluidization, and increases with a decrease in fluidization quality.

The average pressure-drop deviation was obtained by measuring the area between the curve and a line representing the average pressure drop, and dividing this area by the number of seconds over which the record was taken. A polar planimeter was used for measuring the area. The frequency was obtained by counting the number of significant pressure-drop fluctuations per unit of time. The index has the net units of  $100[(\text{lb./sq.in.})(\text{sec.})/\text{cycles}]$ .

It should be noted that the index has been expressed in terms of the average pressure-drop deviation, rather than the per cent average pressure-drop deviation which would have corresponded to the form proposed by Morse and Ballou. This was done because the quality did not appear to be dependent on the magnitude of the pressure drop itself, but rather upon the deviations in pressure drop.

The quality meter was tested on fluidized beds of glass beads under a variety of conditions. Results of a number of runs have been shown in Figures 4-7, in which the quality index has been

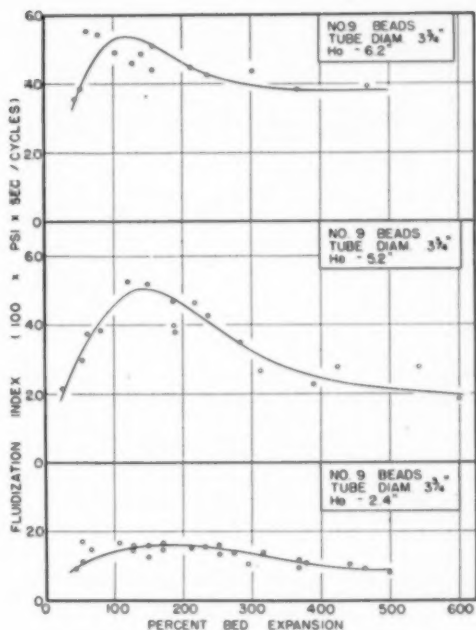


Fig. 5. Fluidization index vs. per cent bed expansion.

plotted against per cent bed expansion. It was found convenient to compare results in terms of bed expansion rather than flow rate since the minimum fluidization velocity varied over a wide range for different particle sizes, initial bed heights and other bed and fluid properties.

It can be seen from Figures 4-7 that, for a given column diameter, bead size and bed height, the index initially increased (quality decreased) with an increase in bed expansion. With a further increase in bed expansion, however, the index leveled off and then decreased (quality increased) as the beads became more widely dispersed. This latter condition appeared to correspond to the state of particulate fluidization as described by Wilhelm and Kwauk (5). In the particulate range the quality appeared to be good.

The effect of initial bed height on the quality may be observed by comparison of the curves given in each of the Figures 4-7. In general the quality decreased as the bed height increased. This is in accordance with the observations of other investigators.

In Figures 6 and 7 results have been given for the same bead size but different column diameters. Results indicate that as the height-to-diameter ratio increased, the quality decreased. However,

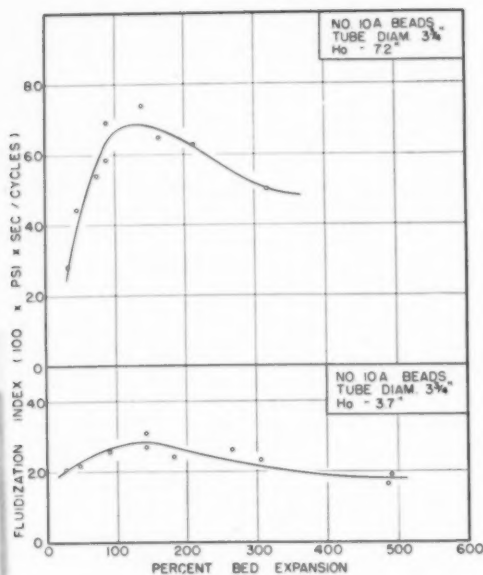


Fig. 6. Fluidization index vs. per cent bed expansion.

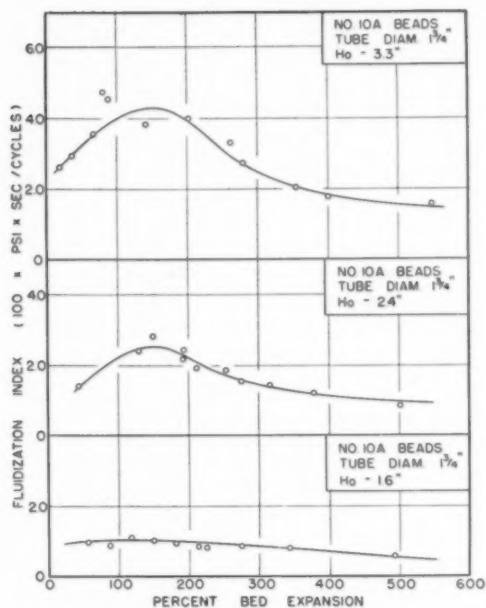


Fig. 7. Fluidization index vs. per cent bed expansion.

for approximately the same height-to-diameter ratio, the quality was better for smaller diameter tube.

The effect of bead size is not readily apparent from these results since the initial bed heights were the same in only a few instances for different particle sizes.

In Figure 8 the variation of the fre-

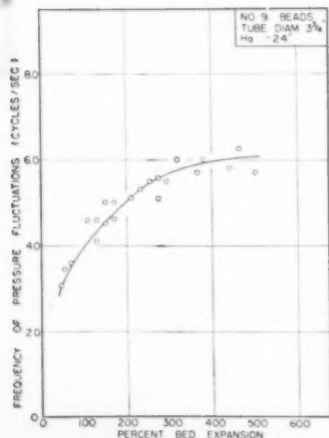


Fig. 8. Frequency of pressure fluctuations vs. per cent bed expansion.

quency of fluctuations with bed expansion has been shown for one bead size. It may be noted that the frequency increases with an increase in bed expansion. At higher bed expansions, corresponding to the state of particulate fluidization, the frequency shows a tendency to level off.

Data presented in this paper are intended primarily to demonstrate the applicability of the quality meter. These data have been limited to one material and caution should be observed in extending them to conditions other than described.

It should be noted that there are certain limitations to the use of the quality meter. Since the instrument measures the drop in pressure between two points in the bed, the measurement represents average conditions between the points. If the section being studied is unduly large, local-point conditions may tend to be obscured. Care should also be observed in the selection of the size and length of tubing selected for pressure connections. Unduly long and small-diameter tubing may tend to dampen the pressure fluctuations.

### Summary

The quality meter will prove useful in the study of the factors influencing

fluidization in that it allows a ready comparison of results on a common basis of quality or uniformity. It was used in the investigation of certain variables on the quality of fluidization. While the conditions investigated were rather limited in range, the results indicate the utility of the instrument in such studies.

It should be pointed out that in all cases the quality, as indicated by the fluidization index, was confirmed by visual observation.

### Acknowledgment

The assistance and suggestions of Prof. R. H. Trathen on the application of strain-analysis theory to this problem are gratefully acknowledged.

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# WASTE CONTROL AT OIL REFINERIES

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**T**HE petroleum refining industry is making progress in its efforts to control water pollution. This paper describes briefly current waste control practices. It is a review of (1) the chief problems in disposal of liquid refinery wastes; and (2) methods which have been developed to provide satisfactory solutions to a number of these problems.

**Joint Industry Action.** Joint industry action was started in 1928 when the American Petroleum Institute organized the first technical committee on waste disposal. In 1930, the original committee was disbanded and the Committee on the Disposal of Refinery Wastes was organized as one of three waste disposal committees for the entire petroleum industry. The Committee on the Disposal of Refinery Wastes promptly initiated a plan of action for the accumulation and dissemination of knowledge on water pollution control.

Since that date the committee has sparkplugged waste control action in the petroleum refining industry. The Committee has published a manual of good practice (2) which includes design information on the A.P.I. oil-water separator. In order to increase its knowledge of the fundamental laws governing oil-water separation, the Committee sponsored basic research projects at New York University and the University of Wisconsin. Results of this research will form the basis for new recommendations on the design of gravity differential-type oil-water separators (24). The Committee has also sponsored fundamental research to evaluate the effects of refinery wastes on bacterial and invertebrate forms of aquatic life (17). The Committee has also published a manual of good practice for Chemical Wastes (3) and is currently accumulating information for a new edition.

## Disposal Problems

The waste disposal problems confronting the refiner include the control of

pollution by free and emulsified oil; both acidic and alkaline chemicals; taste and odor-producing and toxic constituents and materials exerting both an immediate and biochemical oxygen demand. Such wastes originate from a multitude of refinery processes including fractionating, cracking, polymerization, isomerization, alkylation, chemical-treating and selective solvent-refining of oil stocks; from special chemical manufacturing; from operation of utility and service facilities and from maintenance and repair activities (29, 16, 30). A simplified presentation of the origin of wastes within a refinery is shown in Figure 1.

## Control Methods

Control of water pollution by wastes originating within the refinery is accomplished by:

- Engineering and process design considerations.
- Recovery and utilization.
- Local treatment.
- Good housekeeping.
- Effluent treatment.

**Engineering and Process Design Considerations.** In the petroleum refining industry, waste control is no longer an afterthought but is a factor under consideration during the development, selection and detailed design of new installations. The influence of the study of waste control problems during the development and design stage is manifested in numerous ways. There is a trend in the industry toward the installation of multiple-sewerage and collection systems at new units and in new refinery areas. One system is designed to collect polluted process drainage, another is provided to collect clean cooling water and storm-water drainage and a third is installed to collect sanitary wastes. Surface drainage from process areas, enclosed by curbing, is drained to the process sewerage system; all other surface drainage is drained to the clean water sewer. Simple devices, such as gravity differential oil-water

separators can be used to prevent water pollution by oil and solids that may accidentally obtain access to the clean water sewerage system. Process expansions within existing refinery areas having but a single sewerage system require a different approach to the sewerage problem. Cooling water discharges to the sewers are reduced to a minimum by installing cooling towers. Generally pretreatment facilities such as septic tanks are the minimum provided for sanitary wastes. In a few cases in which effluent treatment facilities, equivalent to those used for the secondary treatment of municipal sewage, are provided, sanitary sewage is discharged directly to the plant sewerage system.

Use of separate collection systems for the basically different types of wastes occurring within a unit is common practice.

Use of dirty water recirculation systems and cooling towers for water from barometric condensers and steam jet vacuum pumps has reduced waste control problems associated with vacuum distillation units. Further reductions are being accomplished by substituting surface condensers for barometric condensers and by providing surface condensers on jet vacuum pumps. In other cases waste control has been accomplished by use of surface condensers in place of barometric condensers in various solvent-refining and chemical-manufacturing processes.

Emulsion losses at a wax-deoiling plant have been reduced by use of a dirty water recirculation and cooling-tower system. Emulsion accumulation is prevented by the use of a demulsifying agent.

Process change, involving the installation of rock and salt towers to remove traces of treating agent remaining in treated light oil, eliminated the necessity of water washing the oil and reduced pollution by oil, sulfides and phenols (15).

In another case the installation of a porous mat in the asphalt stripper at a

The recovery system includes a solvent-drying tower, a stripping tower and a separator with essential appurtenances. The

solvent-drying tower produces dry furfural as bottoms and a minimum boiling-point azeotrope as an overhead. On cooling this overhead, a phase separation occurs to produce a furfural-rich and a water-rich layer. The furfural-rich layer is returned to the drying tower as reflux and the water-rich layer is pumped to a stripping tower. In this tower steam-stripping produces a bottom of minimal furfural content and a minimum boiling-point azeotrope as overhead.

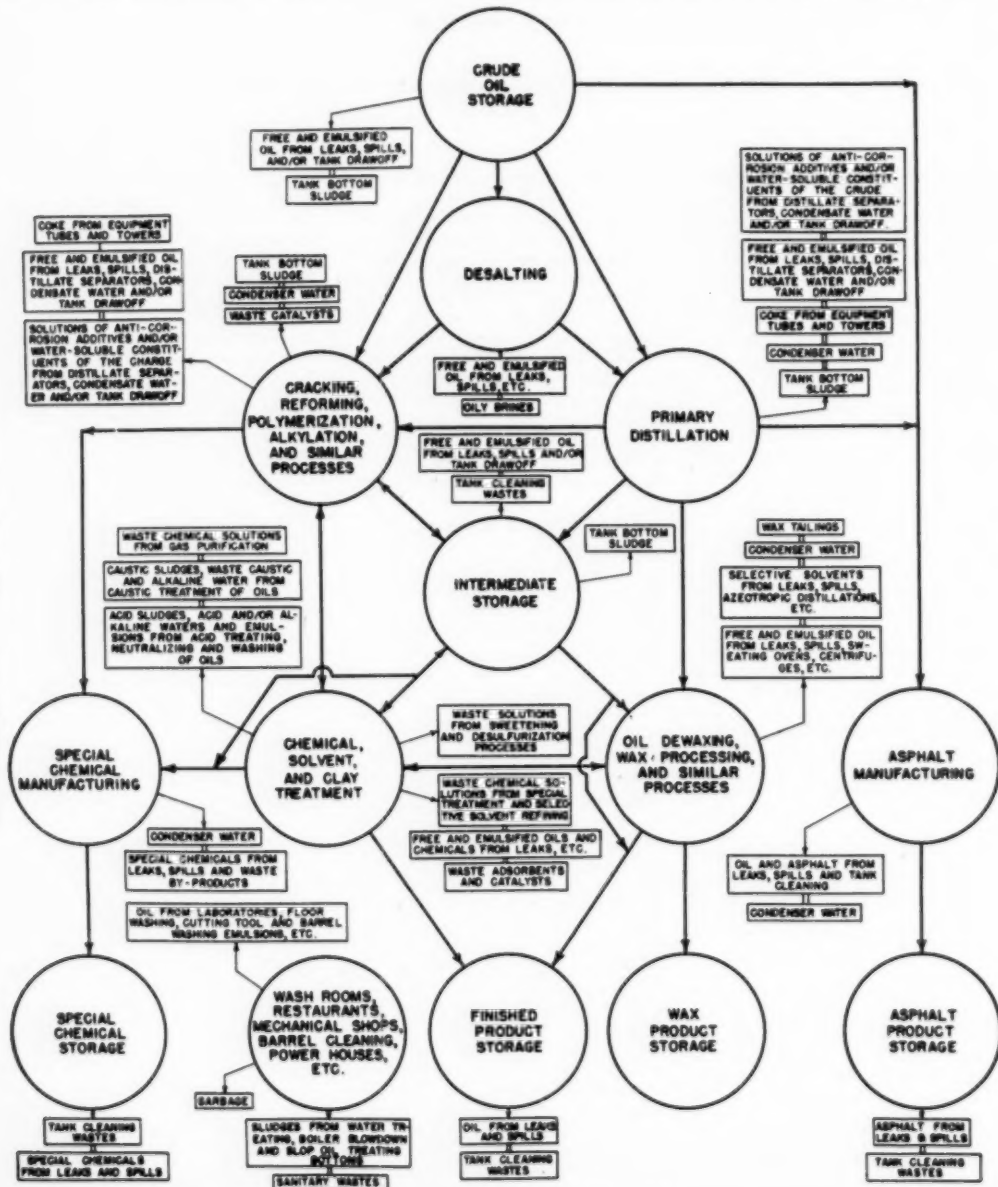


Fig. 1. Typical wastes produced in petroleum refining.

head. This overhead is combined with that from the furfural drying tower. A flow diagram of the process is shown in Figure 2. Furfural losses are controlled to a minimum by altering the normal design criteria for size and operating cost as required by waste control considerations.

Moderate increases in the size and/or operating costs of other standard chemical-recovery facilities have contributed to economical waste control. Methyl-ethyl ketone, phenol- and benzol-recovery processes have been so modified.

The design of continuous- instead of batch-treatment processes has aided in pollution control by eliminating peak discharges of wastes. Thereby, both waste utilization and waste-treatment procedures may be provided at lower cost and may be operated more satisfactorily.

Use of processes which include regeneration of the active chemicals for sweetening, hydrogen-sulfide removal and mercaptan extraction may avoid, or appreciably reduce the problems associated with the disposal of waste caustics.

Other process changes to make more efficient use of chemicals, such as the "down-grading" use of spent caustic from one process as a treating agent for another process, has reduced the waste caustic disposal problem (3).

**Recovery and Utilization.** An illustration of waste utilization in the industry is that of the recovery of sulfuric acid from acid sludges produced in the acid treatment of oils (30). The hydrolysis of sludges produces a dilute (30-60%) black acid. The sludge conversion-contact acid method can produce white acids of 98 to 104.5% concentration. Black acids of the same strength can be produced by feeding weak acids (obtained by hydrolysis) to the towers in the place of clean water.

Spent alkylation acid is reused for treating various oils and waxes and is regenerated in local and outside acid plants (8).

Waste caustics from the caustic washing of catalytically cracked naphthas are high in phenol content. In some cases it has been possible to sell this material directly without processing. In other cases it has been necessary to "spring," i.e., separate the phenolic components from the other constituents by treatment with acidic materials. The flow diagram of a phenol springing unit is shown in Figure 3.

One refinery has installed a waste caustic treatment and acid-oil recovery plant that consists of facilities for storage, reaction of waste caustic with acid and acid-oil separation. The resulting water solution is neutralized with lime, and flocculated using alum. The acid

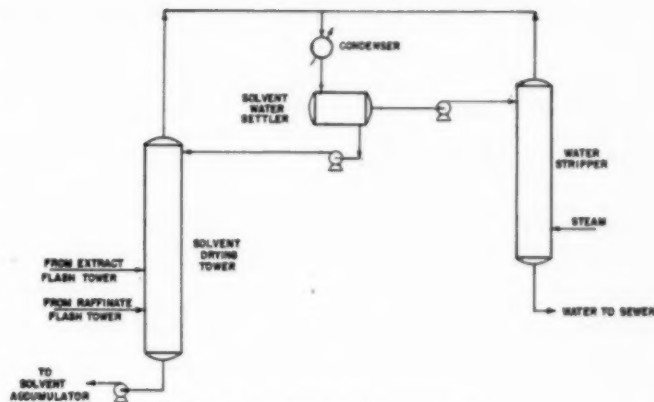


Fig. 2. Flow diagram furfural recovery system.

oils are treated for sale by filtration through diatomaceous earth.

Some waste caustics are used in slop-oil treatment. A chemical flocculation plant at one refinery will use aluminum chloride as a coagulant that has been recovered from aluminum chloride-hydrocarbon sludge (See Fig. 12). Hydrolysis of the sludge produces aluminum chloride, hydrocarbon and benzol. Each component will be recovered and utilized.

Water-treating plant sludge from boiler feed water treatment has been collected and handled in a separate system and used for the neutralization of acidic waste waters. In numerous cases various types of acidic and alkaline wastes are combined for mutual neutralization.

Processing chemicals such as phenol, benzol, etc., lost through pump gland leakage, sample collection, and spills, are collected in a separate drainage system and sump and recovered from the dilute waste solutions. Special stills are pro-

vided for chemical recovery and waste control.

In at least two refineries waste waters have been treated for recovery of usable water. In one case (25) refinery waste is separated to remove free oil, treated with acid to break emulsions, contacted with copperas to precipitate sulfides and reacted with chlorinated lime to oxidize the iron, induce flocculation and reduce odors. The iron floc is separated from the waste water in large settling basins. The clear supernatant is returned to the refinery for reuse. The sludge is dewatered using a filter press and used as fill around the refinery.

In the other case (13) the refinery waste water is separated to remove free oil, clarified and softened using lime, soda ash and ferric sulfate, filtered through high-rate sand filters, acid-treated to control pH and stabilized using polyphosphate. The treated water is returned to the refinery for reuse. The sludge is pumped to lagoons.

All refineries have slop-oil recovery

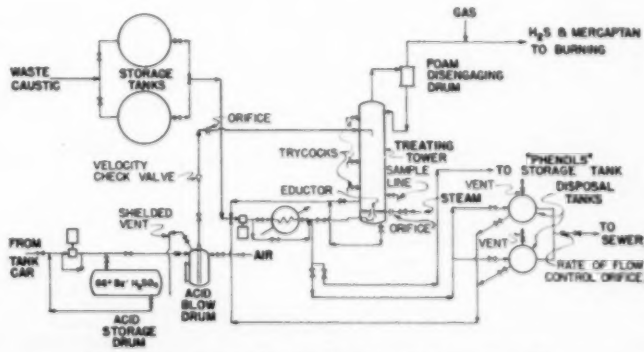


Fig. 3. System for recovering phenolic components from waste caustic.

TABLE 1.—CHARACTERISTICS OF WATER LAYER FROM SLOP OIL TREATMENT

Source	No. Cases	Characteristics *				
		Oil, p.p.m.	Suspended solids, p.p.m.	C.O.D., p.p.m.	B.O.D., p.p.m.	pH
Vacuum filtration experiments .....	87	37-130	30-139	800-1,360	77-153	6.9-7.7
Plant samples .....	5	4900-10,300	60-940	22,000-56,000	5660-14,440	10.0-10.2

\* Range shown includes 50% of cases.

systems. In some cases where large quantities of oil originate at a single source, such as, two stage pipe stills with barometric condensers, local slop-oil recovery systems are provided. General refinery slop oils collected from waste water separators and the bottoms of storage tanks are usually treated by heating in the presence of an alkaline-treating agent. In some cases emulsion-

breaking organic chemicals are also added. A typical installation is shown in Figure 4. Wastes from slop-oil treatment are ordinarily high in pollutional characteristics (31). Pollution from this source can be appreciably reduced by the use of precoat vacuum filters for slop-oil treatment (31, 10). (See Table 1). Full-scale installations of slop oil precoat filters are in operation.

**Local Treatment.** The most common type of local treatment is that of the use of oil-water separators for the separation and collection of oil at individual units. Use of local separators has the advantage that contamination of the oil can be kept to a minimum thus decreasing the cost of conditioning the wasted oil and returning it to the process.

It is common practice to treat "white water" emulsions locally. White water emulsions containing 1-3% oil are formed in the water washing of acid-treated lubricating stocks. These emulsions may be treated using heat and calcium chloride. The water layer is satisfactory for discharge to the plant sewers. The oil or soap layer makes a fuel of high-ash content.

Waste caustics are treated by various methods. Those waste caustics high in organic matter content are generally neutralized to "spring" the "acid oils," i.e., the phenolic and naphthenic materials insoluble at pH values eight and lower. Acid oils are generally sprung using sulfuric acid: Spent alkylation acid, hydrolyzed black acid, and fluid acid sludges are used for treatment. In the treatment process hydrogen sulfide is released. This is burned or utilized for sulfuric acid production. Experimental work has demonstrated that sulfur dioxide also will spring acid oils. Waste caustics high in mercaptans are usually regenerated by steam stripping with open steam in a bubble-tray column. A waste caustic regeneration and mercaptan-stripping system is illustrated in Figure 5. Waste caustics high in sulfides are treated by contact with steam and air and by stripping procedures. The sulfides in the waste caustic contacted with air and steam are converted to thiosulfates. This type of system operates with approximately 95% conversion (15). A simplified flow diagram for stripping hydrogen sulfide from waste caustic. Flue gas is used also for the pH neutralization of waste caustics. Waste caustics have been disposed of by injection into underground formations via disposal wells.

Condensate waters high in ammonia and hydrogen sulfide are treated in some cases using steam stripping (1). A typical system is shown in Figure 7. The

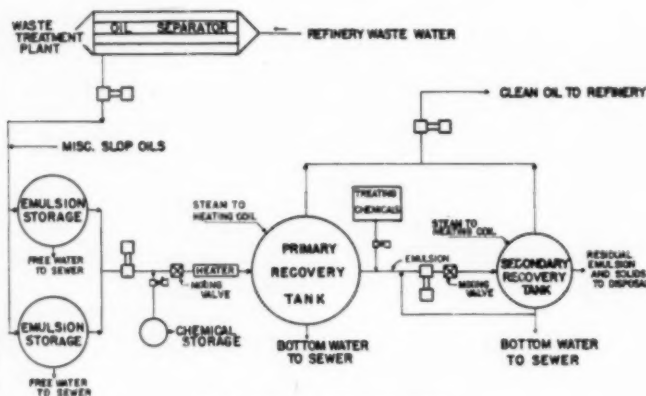


Fig. 4. Batch slop oil recovery system.

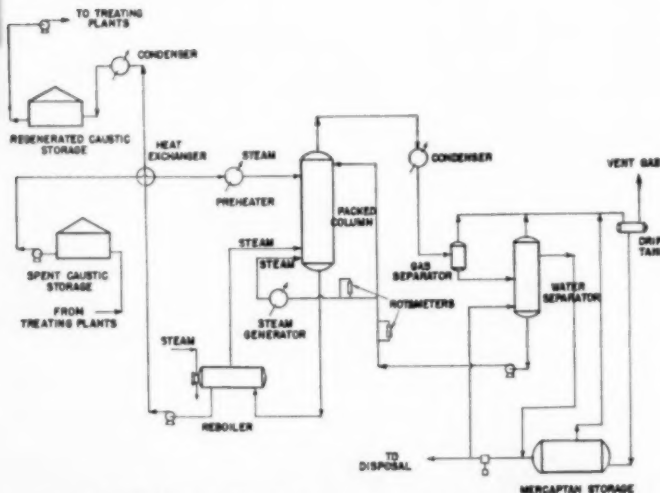


Fig. 5. Flow diagram regeneration system for caustic containing light mercaptans.

ammonia and sulfide appear to exist in these solutions as polysulfides. These polysulfides are decomposed in the process so that ammonia and hydrogen sulfide is stripped overhead. The overhead gases are usually burned. In at least one case, however, the ammonia is recovered as ammonium sulfate by reaction with waste sulfuric acid sludge. Crystallization and drying processes produce an ammonium sulfate of good quality for fertilizer. In some cases condensate waters may be treated by aeration. Ammonia and small amounts of hydrogen sulfide are released by the aeration and colloidal sulfur is precipitated. Sometimes pH control is needed as an adjunct to this process.

At fluid catalytic-cracking units it is common practice to inject a part of the condensate or accumulator waters into the catalyst regenerator gas stream. This may be done before or after the Cottrell precipitators. Temperatures of the gas stream are sufficiently high to destroy the polluting materials.

In some cases, phenolic waters and waste caustics have been satisfactorily disposed of by injection into furnaces or stacks.

Phosphoric acid catalyst has been satisfactorily handled by dumping into a leaching pit, covering with water, leaching at a slow continuous rate by displacing water from the pit, draining off the water and disposing of the neutral Kieselsol or clay as fill. Spent phosphoric acid catalyst is also disposed of by sale for use as soil fertilizer.

The formation of emulsions during barrel-washing operations has been prevented by the addition of calcium chloride to the recirculated wash water. This expedient made it possible to abandon local emulsion-treating equipment.

**Good Housekeeping.** The importance of good housekeeping practices cannot be overstressed.

The education of operating personnel and their supervisors relative to the total cost of the loss of various products and intermediates to the plant sewers is highly essential. A close, friendly, and cooperative relationship must be established between the operating and the waste control personnel. At one refinery it was found that the publication of a cartoon type of illustrated booklet was highly beneficial in selling the idea of controlling oil losses and in obtaining good separator operation (11).

All refineries have an individual or group responsible for waste control activities (32, 18, 4). However, nearly all companies have individuals in each of their various departments who are responsible for specific phases of waste control. Some companies have special waste control laboratories (5), and

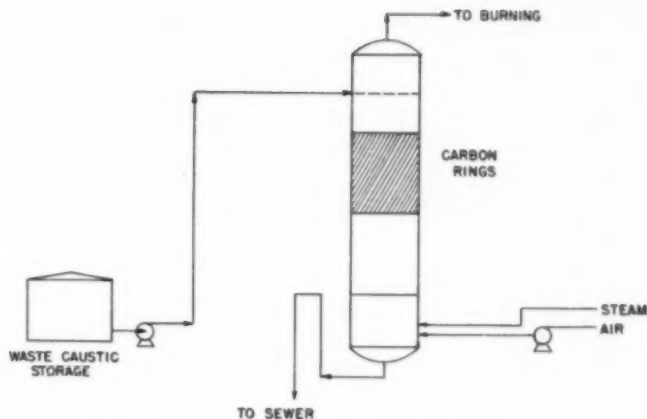


Fig. 6. Oxidation system for waste caustic containing sulfides (see Fig. 5).

employ sanitary chemists, biologists, and engineers trained in the science and art of waste control. Two large refineries have staffs of fourteen to sixteen technicians in a single department who work on waste survey, research and process development activities.

In at least one refinery, control of connections to the sewerage system and changes in waste quality and quantity is made possible by the use of a sewer permit system. Applications for permits to make changes must be approved by the plant manager and by the superintendent of waste control.

Careful operation will help appreciably but the operator must have the use of adequate facilities. For instance, tank bottom draw-offs are generally

made into funnels with adequate air gaps and so located that visual inspection of the draw-off is possible. In some cases, visual inspection alone is not enough to determine the proper point to stop draw-off; in such cases it is necessary to have conductance or dielectric type (28) of instrumentation.

Leaks and spills are practically unavoidable at some locations and samples can seldom be returned to the process directly. Therefore, local facilities for the collection of lost products are frequently provided to encourage good housekeeping and to control losses.

**Effluent Treatment.** Practically all refinery wastes pass through gravity-differential-type oil-water separators

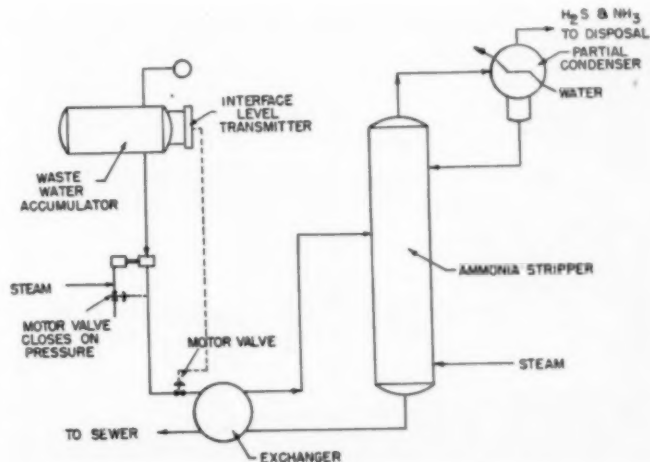


Fig. 7. Treatment system for condensate containing  $\text{NH}_3$  and  $\text{H}_2\text{S}$ .

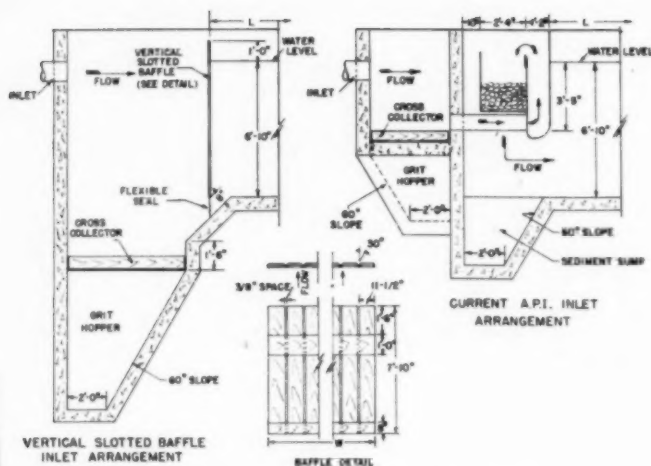


Fig. 8. Comparison of two separator inlet arrangements.

prior to discharge to a natural water course. Good practice in separator design has been described (2). Discussions of these recommendations (24, 20, 31, 19, 14, 21, 7, 26, 22) and descriptions of various installations reveal that there is considerable difference of opinion relative to the merits of some of the separator inlet and outlet details. Use of vertical slotted baffles at the inlet is gaining preference over the conventional A.P.I. inlet structure. A comparison of the vertical baffle and conventional A.P.I. inlet arrangements for a proposed installation is shown in Figure

8. Observations (31) indicate that the design droplet diameter should be reduced from 0.020 to about 0.013 cm. to provide a more realistic design basis.

The sludge that accumulates in these separators is generally disposed of into lagoons. Facilities under construction at one refinery will provide for dewatering and incinerating these sludges. At one refinery oil is recovered from the sludge by blowing with air (6). The oil content of the sludge is reduced from 20-30 to 6-10 per cent.

Experience at several localities has demonstrated that separation treatment

alone is not adequate. This is due to the fact that portions of the oil content of refinery waste water streams are not susceptible to gravity-differential separation and that separators are ineffective in removing materials causing taste and odor, toxicity and B.O.D. Effluent treatment processes in use include filtration through sand (31), flotation (12), and chemical flocculation (23).

Filtration of separator effluents through porous media such as sand is particularly applicable for those cases in which oils of high specific gravity are being separated or for those cases in which there is a definite correlation between oil and suspended solids content (31). For such cases the relative oil removal can be expected to equal or exceed the relative suspended solids removal. The process will probably be effective in removing only suspended solids and oil. Operating data are shown in Table 2. A photograph of an installation is shown in Figure 9.

Dissolved air-flotation processes both with and without flocculation have been used on waste water effluents containing oil (12). Plant scale units are in operation on both oil field brines and refinery waste waters. Reports indicate that air flotation aided by a coagulant and a coagulant aide such as activated silica will produce an effluent containing oil concentrations of 10 p.p.m. or less. Substantial reductions in the B.O.D. of oil field wastes have been reported (12). A picture of a 250 gal./min. unit is shown in Figure 10.

Chemical flocculation of refinery effluents has been used at several locations. As described earlier, the effluents from two such installations (25, 13) are being recycled for plant use. An installation at Clarkson, Ont. (23), has produced an effluent with average oil concentrations less than 5 p.p.m. At one refinery (27) the principal polluting substance is a sulfonate. Treatment by acidification to pH 5 followed by precipitation of the sulfonic acids using lime at pH 7.0 to 8.4 provides color reductions of not less than 98% and oxygen consumed reductions of not less than 92%.

The flow diagram of a 9.6 million gallons per day flocculation plant now under construction is shown in Figure 11. This plant includes an oil separator, acid neutralization facilities flocculation and sedimentation equipment and sludge dewatering and incineration facilities. The waste waters will be neutralized using lime and water-treating plant sludge. Aluminum chloride recovered from aluminum chloride-hydrocarbon sludge will be used as the coagulant. Activated silica and ground spent percolation clay will be used as coagulant aids. The sludge produced will be dewatered on vacuum precoat filters and incinerated in a single hearth furnace with excess production of heat. A storm water basin with capacity to store a one-year storm is provided to reduce pollution during storm per-

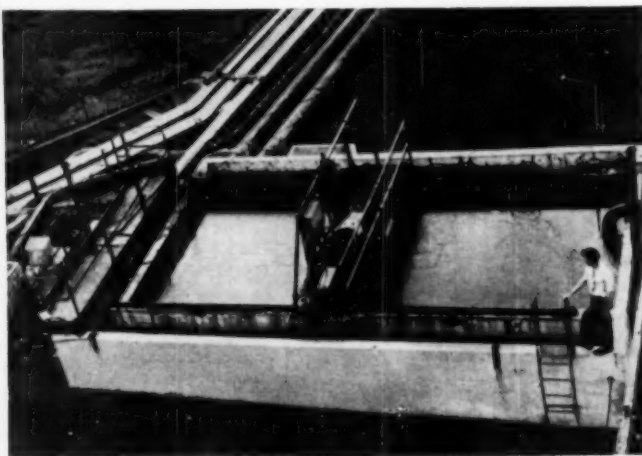


Fig. 9. Photograph of automatic backwash filter installation.

Detailed construction drawings are now in the process of development for treatment facilities using a biological filter. The proposed flow diagram is shown in Figure 12. In each of the above-mentioned cases the design is based on approximately 70% reduction in B.O.D. and reductions in oil content to 10 p.p.m.

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Run no.	Influent Characteristics, p.p.m.				Effluent Characteristics, p.p.m.				% Reductions				Ave. Effluent Rate, gal./min./	Remarks <sup>4</sup>	
	Type	Oil	B.O.D.	C.O.D. <sup>2</sup>	Type	Oil	B.O.D.	C.O.D. <sup>2</sup>	Oil	B.O.D.	C.O.D. <sup>2</sup>				
25	101.0	15	...	89.0	5	61.0	3	...	80.0	39.6	0.31	...	31.5	...	C
26	87.0	8	12.0	104.0	15	47.0	3	7.1	46.4	38.3	0.39	40.8	42.3	0.39	C
24	96.5	15	...	107.0	6	60.5	2	...	71.0	75.0	0.45	...	38.6	0.45	C
28	84.0	27	9.6	112.0	10	51.5	2	5.7	93.0	38.7	0.35	40.6	17.0	0.35	C
27	89.0	10	...	...	11	51.0	3	...	...	42.7	0.33	...	...	0.33	C
218	46.0	11	...	...	150	26.0	3	...	...	31.2	0.29	...	...	0.29	C
99	100.0	3	25.2	123.0	54	44.5	...	18.9	96.0	45.4	0.36	25.0	30.3	0.36	C
31	106.0	19	...	100.0	7	70.0	5	...	77.4	34.0	0.40	...	24.0	0.40	C
24	112.0	26	...	109.0	9	53.0	3	...	86.0	62.6	0.37	...	19.3	0.37	C
88	92.2	...	...	197.0	11	48.5	7	13.8	59.2	75.1	0.47	14.3	70.1	0.42	C
39	80.5	31	...	...	9	37.0	7	...	76.3	64.1	0.35	...	...	0.35	C
33	87.5	14	...	...	12	42.3	7	...	69.2	51.6	0.31	...	...	0.31	C
24	60.0	2	...	59.0	16	34.0	0	...	50.6	43.4	0.24	...	40.7	0.24	C
23	65.0	7	...	95.0	12	26.0	0	...	72.0	60.0	0.26	...	24.2	0.26	C
29	71.0	5	...	...	14	28.0	7	...	51.7	60.6	0.35	...	...	0.35	C
20	40.5	7	...	115.0	7	20.0	1	...	83.0	65.0	0.31	...	27.8	0.31	C
	2680						7						100.0		8
	620						1						99.8		8
	440						2						99.5		8
	164						1						99.4		8

Backwash Characteristics,  
Oil, p.p.m.

480  
620

<sup>1</sup> Filter area, 286 sq.ft.; filter backwash rate, 100 gal./min.  
<sup>2</sup> C.O.D. = chemical oxygen demand using iodine acid.  
<sup>3</sup> T = trace.  
<sup>4</sup> C = 24 hr. composite sample; S = spot sample.

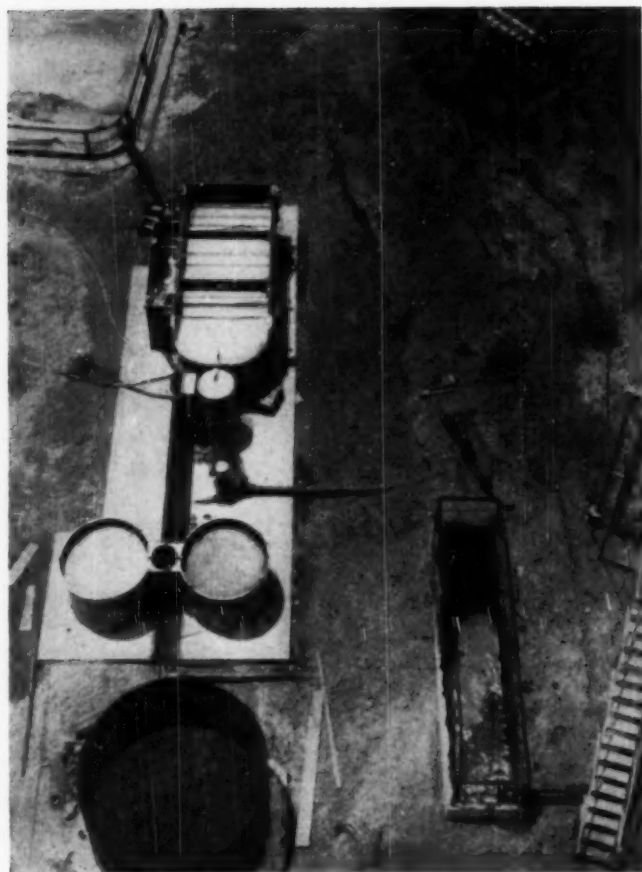


Fig. 10. Photograph of a 250 gal./min. Colloidair separation unit.

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### Discussion

**R. N. Giles** (Standard Oil Co. (Ind.) Chicago, Ill.): Mr. Weston's paper brings up to date the general description of petroleum refinery liquid waste treatment procedures in a comprehensive fashion. I quite agree with Mr. Weston that gravity-differential separation of oil from water is often not adequate (for various reasons) and that higher types of treatment are needed. However, I believe it would be unfortunate if anyone drew the conclusion from this that gravity-type oil-water separators are or soon will be passé in petroleum refineries. This simple device can be made to perform at high efficiency with little cost, assuming, of course, that the influent is susceptible to separation

through the force of gravity. Refiners will need the benefits of this device even if local situations require that secondary treatment procedures be applied to the effluent.

Mr. Weston touched upon the disposal of the bottom settlings or sludges from oil-water separators. There is much to be done in developing an effective and low-cost method of dewatering and deoiling this material prior to its disposal as fill. Commonly, these sludges are withdrawn from the separators as rather dilute suspensions containing about 2% solids contaminated with oily matter. In fact, we should say "oily matter contaminated with solids" since the water-free sludge contains about 2.5 parts by weight of oily matter per part of solids. The dilute suspension can be partially dewatered by settling in lagoons but the only effective process known to date for resolving this sludge is that of continuous precoat filtration. Various other methods have been tried without success. Some of these are: aeration, acidification, hot settling, use of demulsifying chemicals and thickening. In precoat filtration a "dry" cake is obtained which contains about 45% by weight of water, 45% solids and 10% oily matter. (Here the weight ratio of oily matter to solids is only 0.2 to 1.) The filtrate separates cleanly into oil and water phases. However, precoat filtration is expensive and in some cases it might still be necessary to incinerate the cake to free it of oil.

As I understood the system for recovering phenolic components from waste caustic, the waste liquor from the springing operation is drained to the refinery sewer at a controlled rate. Due to the very high threshold odor number of this material I do not feel that this is a sound method of disposal, especially to receiving bodies of water which are fresh.

In the vertical slotted baffle inlet arrangement for a separator the slide seemed to indicate that there was an 8-in. wide opening between the lower edge of the slotted baffle and the floor of the separators and this opening communicated directly with the separator chamber. How is this opening sealed? If it is not sealed then the slotted baffle would have little chance to perform as a flow distributor.

**R. F. Weston:** Concerning the disposal of phenolic wastes, the waste disposal procedures used can be determined by local circumstances. In the case referred to in the paper, the springing operation gave between 80-90% reduction in phenol. Such reductions were adequate for the local conditions.

Concerning the opening under the vertical slotted baffle, this opening is sealed. Unfortunately, the slide as

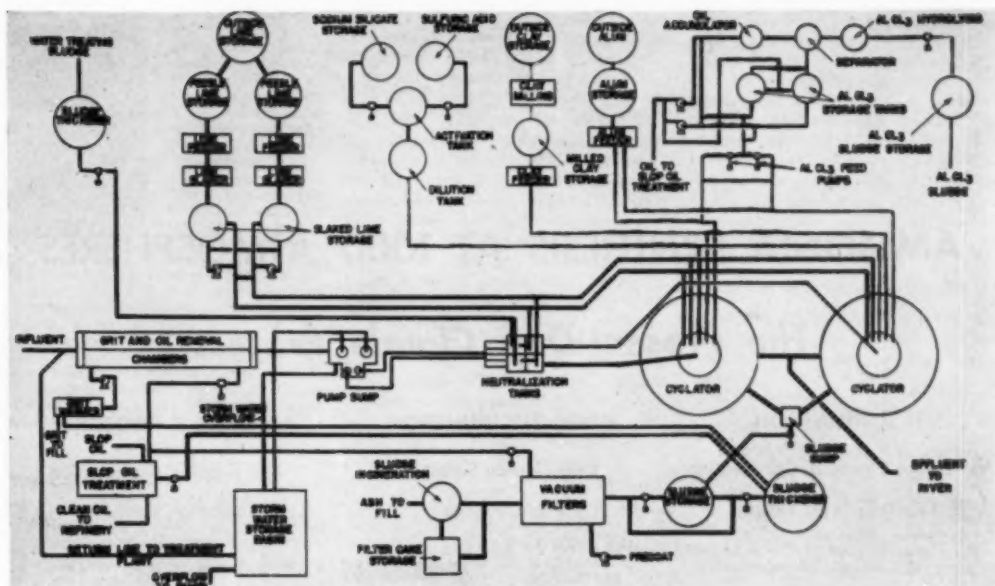


Fig. 11. Simplified flow diagram of a chemical flocculation waste treatment plant.

shown earlier omitted a flexible membrane seal which should be provided over the 8-in. opening. This seal must be flexible to permit the passage of sludge into the sludge hopper.

**D. A. Dahlstrom** (Northwestern University, Evanston, Ill.): Could you elaborate a little on your oil-water separator? What is the throughput velocity and the retention time? Did I also understand you correctly in that the effluent water had only 10 p.p.m. of oil remaining in the water?

**R. F. Weston:** It can be expected that the oil content of waste waters receiving chemical flocculation treatment will be of the order of magnitude of 10 p.p.m. or less. Under favorable circumstances it is possible also to obtain oil concentrations of 10 p.p.m. or less in the effluents from oil-water separators. Effluent oil contents of this order of magnitude are obtainable only when well-designed separators are provided for separating oils of low specific gravity from water that has a low suspended-

solids content and contains no emulsion-producing substances.

Modern A.P.I. separators are designed employing scientific principles which use the specific gravity of the oil, a standard oil droplet diameter, Stokes' law, hydraulic formulae, engineering safety factors and assumed conditions of operation as a basis for design. The A.P.I. does recommend a standard size of oil droplet of 0.02-cm. diam., recommends maximum mean horizontal velocities of 2.5 ft./min., and a factor of safety to be used in determining the separator length. Standard detention times are not used as a design basis.

Indications are present that the formulations for determining sedimentation efficiencies, as have been devised by Thomas Camp, formerly professor of sanitary engineering at Massachusetts Institute of Technology, afford a more scientific approach to the design of oil-water separators than that currently promulgated by A.P.I. We have used Mr. Camp's principles in evaluating the efficiency of various separators. In all cases it was found that the effective droplet diameter was approximately 0.013 cm. This smaller droplet diameter may be a more suitable size for design purposes than the 0.02-cm. diam. currently recommended by the A.P.I.

(Presented at A.I.Ch.E. Forty-fourth Annual Meeting, Atlantic City, N. J.)

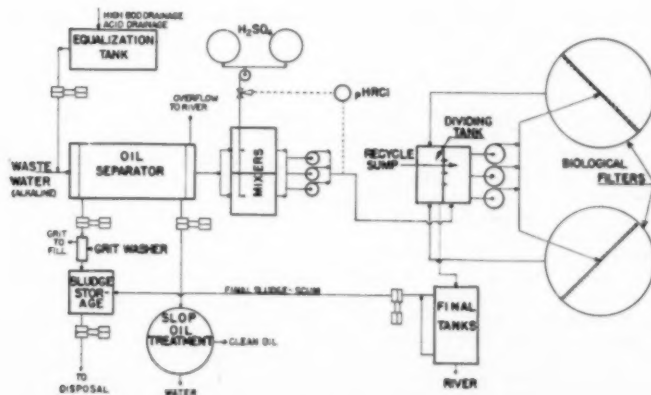


Fig. 12. Proposed effluent treatment system using biological filters.

# AMMONIA SYNTHESIS AT 1000 ATMOSPHERES

## *The Present-Day Claude Process*

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Process design, important equipment items and salient operating features of the Claude high-pressure (1000-atm.) ammonia synthesis process are described, following a brief presentation of factors governing the commercial synthesis of ammonia. The current status is contrasted with obsolete descriptions in United States literature. Certain aspects of the Claude system are compared with those of the better-known 300-atm. ammonia synthesis processes. The present-day Claude process comprises final purification of synthesis gas by catalytic conversion of carbon monoxide to methane (methanation), and conversion of the hydrogen and nitrogen to ammonia in a circulatory synthesis system usually containing two synthesis converters in series, with the necessary cooling, condensing, and separating equipment for ammonia recovery, and a gas-circulating compressor. Continuous purging is practiced to control the concentration of inert gases in the circulatory system. Chemical and operating controls are described briefly, and their simplicity is stressed. The Claude synthesis converter also is described.

RESEARCH and development work on the direct synthesis of ammonia from its elements by Haber and Bosch in Germany during the first decade of this century culminated shortly thereafter in the first commercially successful production of synthetic ammonia. (3). Results of this work stimulated other researchers to develop alternative synthesis schemes, partly in search of improvements over the Haber-Bosch method, and partly to circumvent the elaborate world-wide patent protection wall that was erected around the German development. As a result, other technically feasible ammonia synthesis methods were developed for example in France (Claude), in Italy (Casale) and in Germany (Mont Cenit). Although details of equipment design and methods of synthesis-gas production varied widely, the principal differences in the synthesis processes themselves were in

operating pressures and methods of ammonia recovery. The Haber-Bosch system synthesized ammonia at about 200 atm. and ammonia was recovered from the reacted gas by water scrubbing. Claude and Casale both used much higher pressure—550 to 1000 atm.—and both condensed ammonia by cooling the gas stream, the former with water to usually ambient temperatures and the latter by mechanical refrigeration to temperatures in the neighborhood of 32° F. The Mont Cenit process used 100 atm. and water scrubbing.

Original work on this problem lagged in the United States until World War I, at which time the cutting off of nitrogen imports caused a severe shortage. The Federal government then began an intensive program of research and development on all phases of ammonia production. The work not completed at war's end, was continued for some years

at the Fixed Nitrogen Research Laboratory. Its investigations resulted in a workable ammonia-synthesis system, sometimes called the American process, many details of which were published (3). Several engineering firms and consultants used this development, with various modifications, including an increase in pressure of operation from 200 to about 300 atm., as the basis for ammonia-plant designs all over the world in the thirties and late twenties. Of the ten ammonia plants financed by the U. S. Government in preparation for World War II, six were based on the modified American process. Recent descriptions of plants based on this process have been provided (6, 7, 8).

The earlier processes for direct synthesis of ammonia were developed and exploited by private interests. This is true of the Claude process.

Georges Claude, the French scientist well known for his work on gas liquefaction, dissolved acetylene and neon lighting, began development work in 1917 on an ammonia-synthesis process characterized by use of operating pressures near 1000 atm. compared with 200 to 300 atm. for most of the other processes. Successful operation of a small commercial unit (about 5 tons/day) began in 1921 at Grande Paroisse near Montreuil and two more units of the same size were started at Bully-les-Mines in 1922. Concurrently with the process and engineering development, Claude's French companies, L'Air Liquide Société and Société Chimique de la Grande Paroisse, perfected special



**H. L. THOMPSON**, vice-president and technical director of Mississippi Chemical Corp., Yazoo City, Miss., is a chemical engineering graduate of Alabama Polytechnic Institute (1941). Formerly staff consulting chemical engineer with the Tennessee Valley Authority at Wilson Dam, Ala.,

he initiated and has directed the technical program of his company beginning with its incorporation in 1948. His affiliations include American Association for the Advancement of Science, and Southern Association of Science and Industry. He is a licensed professional engineer in Mississippi. He was chairman of the Wilson Dam Section of the A.C.S. in 1948.

metals and compressor designs required for construction and operation of the Claude units. Between 1922 and 1927 several of these units were installed in various countries, including France, Belgium, Italy, Spain, Japan, Poland and Czechoslovakia. By 1927, several improvements had been made in the process, and a fourfold increase in production of a single unit or train (up to 20 tons per day) had been achieved by these process improvements, plus some design changes. About this time the 20-ton-per-day design was used in new plants in France and in the United States. Five of the 20-ton units were installed at Belle, West Va., for Lazote, Inc., a jointly owned subsidiary of L'Air Liquide and the Du Pont Co. The French interest in Lazote was acquired by Du Pont in 1933, and further modifications were made in the Claude system. These were based largely on features of the Casale process, American rights to which also had been acquired by Du Pont. The French companies made somewhat similar modifications to the French design at about the same time, and increased the size and capacity of the production units.

In December, 1938, Hercules Powder Co. selected the Claude process for its entry into ammonia manufacturing in California. The French companies pro-

vided process and equipment designs for a 40-ton/day plant (later boosted to 90 in two trains) which started production in March, 1940. Five similar trains were designed and built in 1941 and 1942 at Louisiana, Mo., as part of the Government-financed expansion of nitrogen-production facilities for World War II. Hercules was the prime contractor and plant operator, again using the French designs and know-how. After the war was over the U. S. Bureau of Mines took over three of these five units for experimental work in connection with its synthetic liquid fuels program. The other two units were moved by the army to the San Jacinto Ordnance Works near Houston, Tex., where cheaper natural gas and electric power were available (4). These units were leased early in 1950 for operation by a private company.



**PIERRE GUILAUMON**, graduated from the Paris Engineering School "Ecole Centrale," is a senior engineer of the Air Liquide Group. Working first with Georges Claude, he is particularly familiar with a high-pressure process for ammonia synthesis. To demonstrate this process he was invited to this country in 1925. Since, he has made frequent trips here and has spent more than ten years of his life in the United States. A veteran of World War I, following a short service period on the Maginot Line, he collaborated with this country's officials on the defense program during World War II.

Mississippi Chemical Corp. chose the Claude ammonia-synthesis process in April, 1949, for use in its projected 120-ton-per-day ammonia plant at Yazoo City, Miss. The L'Air Liquide design for this plant provides for two 60-ton-per-day trains. The Girdler Corp. was retained by Mississippi Chemical as de-

sign engineers and constructors to work with L'Air Liquide.

In addition to the American plants just mentioned, the Government ammonia plant at Morgantown, West Va. was designed and built by Du Pont using a synthesis pressure near 1000 atm., and Du Pont has one other small plant said to use this pressure. Accordingly, six out of about 20 U. S. ammonia plants are based on the so-called high-pressure synthesis.

## Ammonia-Synthesis Fundamentals

Certain fundamental considerations, common to all the ammonia-synthesis processes in commercial use, are as follows:

1. Processes are based on the reversible all-gas reaction:

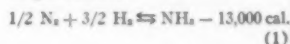


Table I, based on Fixed Nitrogen Research Laboratory results, shows the equilibrium ammonia concentration at various temperatures and pressures after reaction of pure hydrogen-nitrogen mixtures in which the  $H_2/N_2$  ratio equals 3.

2. Presence of inert diluent gases, such as methane or argon, or a deviation in the  $H_2/N_2$  ratio, causes reduction of ammonia content at equilibrium.
3. Reaction rate is infinitesimally small in the absence of a suitable catalyst (usually magnetic iron oxide promoted with aluminum and potassium oxides).
4. Since the reaction is reversible, conversion rate to ammonia approaches zero as the ammonia content approaches equilibrium. Equilibrium conversion upon a single exposure of the gas to reaction conditions therefore is not feasible.
5. Even in the presence of otherwise suitable catalysts reaction rate is impractically small at temperatures below about 400° C.

**NORMAN C. UPDEGRAFF**, assistant technical director, gas processes division, The Girdler Corp., Louisville, Ky., was graduated from Harvard in 1940 with an A.B. degree in engineering sciences. After a short spell of development work with General Foods he joined Du Pont



in 1942 where he worked as a production supervisor in neoprene manufacture. He has been with Girdler since 1946, specializing in process design of plants for the production, purification and use of various industrial gases. He has been active in local section activities of A.I.Ch.E. and is a member of the National Association of Corrosion Engineers and the Harvard Engineering Society.

TABLE I.—EQUILIBRIUM AMMONIA CONCENTRATION (%) AFTER REACTION OF 3/1 HYDROGEN-NITROGEN MIXTURE (3)

Temperature °C.	Pressure (Atm. Abs.)						
	10	30	50	100	300	600	1000
200	50.66	67.56	74.38	81.54	89.94	95.37	98.29
250	28.34	47.22	56.33	67.24	81.38	90.66	96.17
300	14.79	30.25	39.41	52.04	70.96	84.21	92.55
350	7.41	17.78	25.23	37.35	59.12	75.62	87.46
400	3.85	10.15	15.27	25.12	47.00	65.20	79.82
450	2.11	5.86	9.15	16.43	35.82	53.71	69.69
500	1.21	3.49	5.56	10.61	26.44	42.15	57.47
550	0.76	2.18	3.45	6.82	19.13	31.63	41.16
600	0.49	1.39	2.26	4.52	13.77	23.10	31.43
650	0.33	0.96	1.53	3.11	9.92	16.02	20.70
700	0.23	0.68	1.05	2.18	7.26	12.60	15.87

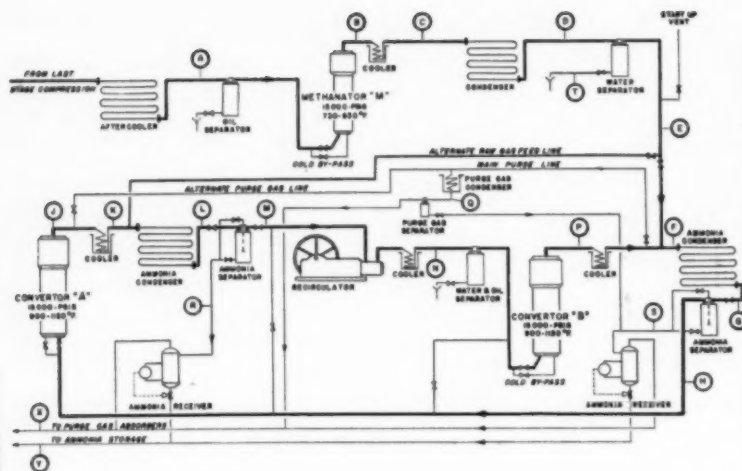


Fig. 1. Process flow diagram—Claude ammonia synthesis.

NO.	TEMP.	IN.	OUT.	CONCENTRATION, MOLE %	AMMONIA	CO	N <sub>2</sub>	H <sub>2</sub>	CH <sub>4</sub>	Ar
A	80	500.0	70.4	15.0	---	0.0	0.0	0.0	0.0	0.0
B	80	500.0	70.4	15.0	---	0.0	0.0	0.0	0.0	0.0
C	80	500.0	70.4	15.0	---	0.0	0.0	0.0	0.0	0.0
D	80	500.0	70.4	15.0	---	0.0	0.0	0.0	0.0	0.0
E	80	499.8	79.8	14.4	---	0.0	0.0	0.0	0.0	0.0
F	80	841.6	57.8	15.0	---	10.0	10.0	1.0	0.0	0.0
G	80-100	---	---	---	---	---	---	---	---	---
H	80-100	673.7	8.8	15.0	---	0.0	0.0	0.0	0.0	0.0
J	80	730.7	44.4	14.9	---	0.0	0.0	0.0	0.0	0.0
K	80-100	---	---	---	---	---	---	---	---	---
L	80-100	---	---	---	---	---	---	---	---	---
M	80-100	680.0	10.0	15.0	---	0.0	0.0	0.0	0.0	0.0
N	80-100	---	---	---	---	---	---	---	---	---
P	80	450.0	40.0	15.0	---	0.0	0.0	0.0	0.0	0.0
Q	80-100	38.8	40.0	15.0	---	0.0	0.0	0.0	0.0	0.0
R	80-100	182.7	9.1	15.0	---	0.0	0.0	0.0	0.0	0.0
S	80-100	87.7	9.1	15.0	---	0.0	0.0	0.0	0.0	0.0
T	300	POUNDS WATER PER HOUR	---	---	---	---	---	---	---	---
X	80	55.7	4.0	15.7	---	0.0	0.0	0.0	0.0	0.0
Y	10,000	POUNDS LIQUID AMMONIA PER HOUR	---	---	---	---	---	---	---	---

1. 1500-1800 PSI, 750-850°F, & ONE ATMOSPHERE

2. MOSTLY IN THE FORM OF LIQUID

- Equilibrium conversion to ammonia becomes very small at high temperatures (Table 1), although reaction rate is favored by higher temperatures.
- Increasing pressure markedly benefits equilibrium conversion (Table 1).
- Increased pressure accelerates the reaction.
- Commercial catalysts are subject to poisoning by exposure to gases containing oxygen, such as CO, CO<sub>2</sub>, and water. Other poisons are sulfur, phosphorus, and arsenic (1). Minute concentrations of these poisons adversely affect catalyst performance and life, sometimes drastically.
- Vapor pressure of liquid ammonia in equilibrium with hydrogen-nitrogen mixture is a function of temperature and total pressure.

These factors largely dictate process and equipment designs for successful ammonia synthesis. For example, preheating of the gas stream before reaction is required by the temperature threshold indicated in (5), while the heat released by the reaction (1) and the desirability of restricting temperature (6) require that heat be removed from the reaction zone. A high purity of the reacting gases is required with respect to catalyst poisons (9), and an indication is given of the desirability of minimizing the inert gas concentration (2). Because of the incomplete conversion at equilibrium (Table 1), as well as the imperfect approach to equilibrium (4), ammonia must be removed from freshly reacted gas and the unreacted gas returned to a reaction zone, either by recycling to a single zone, or by providing multiple zones in series. Ammonia may be recovered by absorption

in a suitable solvent, or by cooling and condensation followed by drawing-off liquid ammonia. In the latter case, the proportion of ammonia removed will be governed by equilibrium conditions such as mentioned in (10).

In practice, complete elimination of inert gases from commercial sources of synthesis gas is not ordinarily feasible, and these gases accumulate in the system. As a result the inerts concentration must be controlled by some method of purging.

The lower limit of operating pressure for commercial ammonia synthesis is determined by the increasing difficulty of achieving satisfactory conversion, of handling large volumes of gases in reaction and heat-transfer equipment, and recovering ammonia in low concentrations, as pressure is reduced. Plant operating pressures as low as 100 atm. have been reported (3). The practical upper limit of pressure is fixed by the availability and cost of equipment and machinery for working at high pressures, and by excessive power costs when the pressure exceeds that required to achieve given objectives. At the time Claude was carrying out his experimental work, a pressure of about 1000 atm. was more or less arbitrarily adopted as sufficient to eliminate the need for mechanical-refrigeration equipment to cool the gases preparatory to ammonia recovery, and to accomplish Claude's other objectives based on use of higher pressures. Pressures of this magnitude (termed hyperpressures by Claude) also were approaching the limit of compression

and metallurgical know-how of the period. In fact, Claude's first attempts to work at these pressures were considered quite bold, both from the mechanical and scientific standpoints. These first attempts were but the starting point of other special research activities, on metals, compression equipment, and mechanical design, the successful culmination of which resulted in the present status of the process.

**Claude Design and Operation.** Figure 1 is a simplified flow diagram for one of the typical Claude synthesis units as currently designed. Concentration of inerts shown in the incoming synthesis gas corresponds to what may be expected when natural gas is used as the source of hydrogen, and boiler flue gas or its equivalent as the source of nitrogen. It may be assumed that the carbon monoxide content has been reduced to 1.5% by catalytic conversion over an iron oxide catalyst according to Equation (2):



and that carbon dioxide has been removed from the gas by absorption, final contact having been with a caustic solution which effects quantitative removal.

Compressed gas at about 15,000 lb./sq.in., having been cooled to remove the heat of the final stage of compression, and passed through oil and moisture separators, enters a methanation step where carbon monoxide is converted to methane and water by reaction with hydrogen, after the gas has been pre-

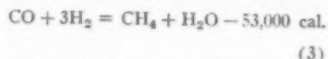
heated by interchange with outgoing hot gas. The water formed is removed by cooling and condensation. The gas then enters the circulatory ammonia synthesis system, first joining a stream of recycled gas in which the inert constituents have been allowed to accumulate to a predetermined concentration. The recycled gas also contains unrecycled ammonia.

The circulating gas stream enters cooling coils where ammonia condenses and is subsequently recovered as liquid from the bottom of a separator. This is followed by the first stage of conversion, precooling, condensation cooling, and separation. The cooled gas next passes through a gas-circulating pump, after which it is recooled and oil is separated from the gas. There follows the second conversion, and then precooling. About 65% of the incoming hydrogen and nitrogen is converted to ammonia on each pass (through both converters).

Following ammonia conversion and preliminary cooling, a controlled quantity of gas is purged for maintenance of the inert concentration at the desired level. The controlled purge does not account for all the inerts that must be removed from the system. Varying amounts of methane and argon, as well as hydrogen and nitrogen, are dissolved in the liquid ammonia, and released upon discharge of the ammonia to lower pressure. This represents an uncontrolled purge, as does the small amount of gas bled out in separator operation, as explained later. The flows shown at *S* and *R* include the dissolved gases. The total material removed at these points is shown in gas units for consistency with the other flows. The distribution between controlled and uncontrolled purge in Figure 1 is illustrative only. Controlled purge is taken at a point where the ratio of "useful" gas (i.e., nitrogen and hydrogen) to inerts is at a minimum. The ratio of ammonia to inerts is not critical since the total purge is washed to recover aqua ammonia, which may be stripped to yield anhydrous ammonia. Following controlled purge, the circulating stream is mixed with fresh make-up gas, which closes the cycle.

**Control of Gas Purity.** Although the method used for synthesis gas purification is not, strictly speaking, part of the synthesis process, in the Claude process final purification (elimination of carbon monoxide) is carried out at synthesis pressure and in equipment that is part of the synthesis plant. The catalytic method used is one of the chief distinguishing characteristics of the Claude system, and has come to be identified as an integral part thereof. In the Claude process, carbon monoxide is eliminated by conversion to methane over an iron-

oxide catalyst similar to the synthesis catalyst, according to Equation (3)



This results in a loss of hydrogen, which accounts for the high hydrogen nitrogen ratio in the synthesis-gas composition of Figure 1. Equation (3) also introduces additional inert gas, i.e., methane, into the synthesis system.

Equation (3) (methanation) compares with so-called copper-liquor scrubbing, which is a common method of final carbon monoxide purification for synthesis systems operating at lower pressures. Copper liquor is an aqueous solution containing cuprous and cupric ions, ammonia, carbon dioxide, and one or more organic acids such as formic, acetic and lactic. The liquor composition must be carefully controlled both as to total concentration of the various ions and as to their mole ratios. This solution is refrigerated and carbon monoxide is absorbed in it at pressures generally in the neighborhood of 100 to 150 atm. Under these conditions, small quantities of hydrogen and nitrogen also are absorbed. After each pass through the absorption tower, the copper liquor is boiled to dissociate the complex carbon monoxide containing compounds formed during absorption. Effluent gases from this operation are treated to recover ammonia and carbon monoxide. The regenerated copper liquor then is recooled and the cycle repeated.

Properly controlled copper-liquor scrubbing is highly effective for carbon monoxide removal, and it also acts as a final barrier against introduction of carbon dioxide into the synthesis system, since the dioxide also is absorbed at the temperatures and pressures used. Final concentrations of combined carbon oxides on the order of only a few parts per million are not uncommon. On the other hand, methanation also provides practically quantitative conversion of the catalyst-poisoning oxides to inert methane. In practice, the methanator effluent gas is seldom analyzed for carbon monoxide content, and methanation is assumed to be complete so long as temperatures are kept in bounds.

Should the temperature of the methanation catalyst increase substantially, synthesis of ammonia would begin, with further, progressive, temperature rise. When this occurs, it is necessary to by-pass more cold gas into the converter or take other steps to lower the temperature.

The effect of decreasing methanator temperature is to favor the synthesis of methanol from carbon monoxide and hydrogen. Also, the conversion of carbon monoxide becomes incomplete and

methyl oxide vapors are formed, which endangers the synthesis catalyst. Accordingly, it is more important to avoid a slightly lower temperature than a slightly higher one, since in the latter case, conversion of carbon monoxide to methane is not impaired.

In practice, the methanation temperature is maintained such that a small amount of ammonia is formed in the methanation converter. Control is primarily by titration of samples of the water condensed following methanation, rather than by temperature observations. Adjustment of the by-pass so that a small constant percentage of ammonia is maintained in the condensate results in sustained satisfactory operation. Little operating attention is required; the operator makes periodic titrations of condensate samples with standard acid and makes by-pass adjustments as they are indicated by results of this titration. Major changes in operating conditions are apparent from the recorded gas temperature entering the reaction zone. A typical life for methanation catalyst is approximately twice that of the synthesis catalyst, and the amount used is about half that required for synthesis. Methanator construction is similar to the synthesis converter, which is described in a later section.

A detailed economic comparison of methanation with copper-liquor scrubbing for final carbon monoxide removal from ammonia, assuming that both are satisfactory from the standpoint of performance, is beyond the scope of this paper, and indeed, such a comparison is pointless in the absence of many qualifying assumptions on conditions in a given case. The principal disadvantage of methanation is the consumption of hydrogen to form methane and water. For this reason, the methanation operation must be charged with the incremental investment and operating costs of compression and gas preparation for that portion of the hydrogen lost due to methanation. It is doubtful if the investment increment for gas preparation can be determined with accuracy in any typical case, because the usual gas plant is rather flexible as to capacity. Furthermore, the incremental operating cost for gas production will be limited almost entirely to increased raw material and fuel consumption, because other annual costs such as operating and maintenance labor, chemical control, etc., should not be affected materially by small variations in throughput. Consequently, incremental charges would be limited to increased fuel and material consumption, compressor investment and compressor-energy cost. Methanation, by increasing the

methane content of the make-up gas, also requires increased loss of hydrogen and nitrogen through purging (assuming a constant permissible concentration of inerts in the circulating gas stream), an effect that increases the incremental charges just summarized.

On the other hand, a copper-liquor scrubbing system requires substantial investment in additional equipment, including scrubbing towers, regeneration and storage tanks, water and ammonia-cooling coils, high-pressure liquor pumps, vacuum and refrigeration equipment, as well as incremental investment in steam-generating capacity for liquor regeneration. From the standpoint of operating cost, copper-liquor scrubbing requires substantial amounts of steam, power for refrigeration and pumping of water and solution, and make-up reagents. The extra labor required for operation, maintenance, and chemical control of a copper-liquor system is significant also.

It is interesting to note that no reference has been found in U. S. literature concerning purification by methanation in the neighborhood of 300 atm., although methanation near atmospheric pressure has been practiced, using a nickel catalyst in the range of 400-600° F. (9). Experimental data on methanation at pressures conforming to those most frequently encountered in American ammonia plants should be of interest to the industry, and provide a better basis for comparative evaluations. It is noted also that several foreign plants use liquid nitrogen scrubbing to remove carbon monoxide and other impurities from ammonia-synthesis gas. The liquefaction and scrubbing equipment is similar to that previously described by one of the authors in connection with use of coke-oven gas for ammonia synthesis (5).

**Control of Hydrogen-Nitrogen Ratio.** In usual practice, maintenance of the desired  $H_2/N_2$  ratio for synthesis requires simply that a constant percentage of  $H_2$  be fed to the methanator. This is true largely because a mole of CO converts the same number of moles of  $H_2$  in Equation (3) as a mole of  $N_2$  does in the ammonia synthesis reaction, so that changes in the  $N_2/CO$  ratio in methanator feed gas do not require adjustment of the incoming  $H_2$  content. The following analysis provides a more rigid demonstration.

Of 100 moles of methanator feed gas, assign the designations  $v, w, x, y$  and  $z$  to the number of moles of  $CO, CH_4, H_2, N_2$ , and  $A$ , respectively. Assuming complete conversion of  $CO$  to  $CH_4$ , the number of moles of outlet dry gas will be  $100-3v$ , of which  $(v+w)$  will be  $CH_4$ ,  $(x-3v)$  will be  $H_2$ , and  $(100-v-w-x-z)$  will be  $N_2$ . By

setting  $(x-3v)/(100-v-w-x-z)$  equal to 3, the required value of  $x$  to maintain the proper  $H_2/N_2$  ratio in the outlet gas is found to be  $3/4(100-w-z)$ . If  $w$  and  $z$  (the incoming methane and argon concentrations) are constant, the required  $x$  value also is constant.

When the ultimate source of nitrogen for synthesis gas is air that has not been liquefied and fractionated, which is the assumption for Figure 1, nitrogen per argon ratio in the synthesis gas will be constant at the atmospheric value of about 84. Consequently, changes of a few per cent in nitrogen content of the synthesis gas will have a negligible effect on the argon concentration, which will be substantially constant at 0.29%. The required  $x$  value then reduces to the expression  $(74.79 - 3/4 w)$ .

Although methane content ( $w$ ) is more subject to change than argon content in most cases, the changes still are small and not likely to be rapid. Therefore the condition that  $w$  and  $z$  remain constant is met closely enough for practical purposes, and maintenance of a constant  $H_2$  concentration in the methanator feed gas is sufficient for day-to-day control. Hydrogen is more soluble in liquid ammonia than nitrogen, and the removal of hydrogen-rich dissolved gas by the recovered ammonia tends slowly to deplete the hydrogen supply in the circulatory synthesis system. Periodic temporary adjustments of the incoming  $H_2$  concentration based on observations of the  $H_2$  content of the circulating gas serve to compensate for this factor.

In practice, the Claude units perform somewhat better with a circulating gas slightly deficient in hydrogen. Optimum  $H_2/N_2$  ratios are in the range 2.85 to 3.0.

**Circulatory Synthesis System.** In Claude's original process design (3), the problem of providing multiple contacts of the gas with catalyst, each followed by ammonia separation, and that of controlling the accumulation of inert gases in the reaction zone were met by installing several small-capacity reaction zones in series. Incoming gas from methanation passed through the first synthesis converter, was cooled with water to condense ammonia, passed through the second converter, cooled, and so on for four stages or more. The volume of gas decreased progressively from stage to stage while the concentration of inerts increased. Purge consisted simply of discharging the effluent gas from the last condensation to atmosphere or to fuel gas use. Under these conditions space velocity (gas flow rate per unit volume of catalyst), which is a reciprocal function of contact time with the catalyst, decreased from stage to

stage. In the first low-tonnage installations, because of the small size of the converters, it was necessary to supply heat to the reaction zone from outside, but later a simple internal heat-transfer design for the converter was devised which rendered the synthesis autothermal in normal operation (3).

However, the advantages of a circulatory system, including constant controlled purge, better operating control due to variability of gas flow through the converters, easy adjustment of  $H_2/N_2$  ratio, etc., led to development of process and equipment designs suitable for circulatory operation at high pressures. Efficient circulatory pumps have been designed for this purpose, reverting essentially to the scheme originally used in low-pressure (300 atm. and below) synthesis and in the Casale high-pressure synthesis (3).

The French operators have retained, for a 120 ton-per-day plant, two converters in series within the circulatory system (Fig. 1). With the series arrangement, a circulator of lower capacity may be used compared with a parallel system. By use of the by-pass valves the conversion load may be varied between the two reactors to compensate for variations in catalyst activity or operating conditions in either. The system also is arranged for reversal of flow so that converter *B* takes the fresh make-up gas. Diminution of activity occurs first in the catalyst exposed to the fresh gas, in part because of the high-heat release at this point where the bulk of the reaction takes place. By reversing the order of flow through the converters, the major conversion duty is switched to fresher catalyst, which tends to lengthen over-all catalyst life. Also, somewhat better recovery of hydrogen and nitrogen is possible with a series arrangement. As mentioned earlier, it is desirable to purge the system of inerts at a point where the ratio of unconverted useful gas to inerts is at a minimum. From the illustrative data of Figure 1, it may be seen that this ratio is approximately 3.7 in the gas stream at *J* and drops to 2.2 at *P*.

Fresh make-up gas enters the circulatory system of Figure 1 just ahead of the condenser coils where gas-stream temperature is reduced to a minimum suitable for ammonia condensation and separation as liquid. An alternative possibility is immediately upstream of the inlet to a converter. The two points of addition are essentially equivalent as concerns total system production. Some operators maintain that make-up feed ahead of condensation results in absorption of trace impurities in the liquid ammonia, and that catalyst activity and

life thereby are benefited (10). This point of make-up gas addition is commonly used in synthesis at lower pressures (7). Other operators of Claude-type plants contend that the reduction in ammonia partial pressure which results from adding this gas just before synthesis improves the conversion. Comparative data are scarce or nonexistent, although both points of addition are in current use.

In the flow scheme of Figure 1, converter *A* takes a larger volume of gas and under normal conditions carries about 60% of the conversion load. Effluent gas from this converter is precooled, cooled to condensation temperature, and passed through a separator. Water is the external medium for both stages of cooling. Since ammonia concentration and gas volume both are higher at point *J*, the ammonia recovered at *R* represents normally about two thirds of the total.

The circulator overcomes 200 to 1000 lb./sq.in. pressure drop through the system, restoring gas pressure at the outlet to between 11,000 and 15,000 lb./sq.in., which is normal operating-pressure range.

Operating conditions shown in Figure 1 are illustrative only, although they are not inconsistent with actual operating observations at Claude plants of comparable design. The by-pass shown at the bottom of each converter is the main temperature control. With fresh catalyst after equilibrium conditions have been established the by-pass is open to keep catalyst temperature down. As the catalyst ages, temperature is allowed slowly to increase by gradual closing-off of the by-pass. This involves a slight drop in conversion efficiency which may require increase of the operating pressure and adjustment of the circulation rate. The temperature ranges shown on the diagram are typical of this cycle. The net increase in gas temperature is more in passing through converter *A*, because of the greater heat of reaction which must be carried off to maintain autothermality in the vessel.

Each converter vessel contains about 16.5 cu.ft. of catalyst, so that the space velocity, in hourly volumes of exit gas at standard conditions per volume of catalyst, is about 44,000 in converter *A* and 30,000 in *B*. In *A*, about 40% of the hydrogen and nitrogen is converted per pass. Space-time yield in *A*, expressed as pounds of ammonia synthesized per hour per cubic foot of catalyst, is 410; the corresponding figure for *B* is 245; and the net yield for both is 320.

These indices may be compared with previously reported values for a synthesis system operating at about 285

atm., space velocities of 9,000 to 11,000 and catalyst temperatures estimated at about 930° F. (1). Inlet- and outlet-gas compositions were quite similar to the example of converter *A* in Figure 1 except that the methane-argon ratio was approximately reversed. Calculated typical space-time yields and percentage conversions were about 48 and 26, respectively. These previous authors estimated conversion efficiency, arbitrarily defined as the ratio of actual to theoretical (equilibrium) ammonia concentration in the effluent gas, as about 0.9. Assuming the same temperature for converter *A*, the comparable conversion efficiency, is calculated to be about 0.5, indicating that the 285 atm. conditions were closer to equilibrium than those assumed for Figure 1.

The objective of using high-synthesis pressures is not only to achieve high conversion per pass. The practicable space velocities and space-time yields are more significant. About one seventh as much catalyst and converter volume is required to produce a given amount of ammonia at the higher pressure as compared with the lower, and four and one-half to five times as much gas must be pumped and piped for the low pressure, on the basis of actual volume at synthesis conditions.

Catalyst subjected to duty at 1000 atm. has a shorter active life, however. The authors just cited reported satisfactory continuous activity of an initial charge of catalyst over a four-year period of operation below 300 atm. Actually their catalyst is known finally to have been in service about seven years. However, this performance is believed to be unusually good, and a more nearly typical active life for catalysts operating at 300 atm. probably is two to three years (11). Catalyst life in Claude 1000-atm. converters is 1500 to 2500 continuous hr., after which activity has decreased enough to warrant changing. The Claude converter is relatively small and the comparison of catalyst life with other processes may be misleading because of the small load of catalyst in this converter. Furthermore, the Claude converter is designed for quick removal of the catalyst basket—or cartridge—and replacement by a previously recharged spare, so that down-time is short. A typical time for the change-over and return to normal operation is on the order of 8 to 16 hours. Most operators schedule preventive maintenance work during the predetermined shutdowns for catalyst replacement, so that the net down-time chargeable to catalyst changing may be quite small. The catalyst used in the Claude process is essentially the same as that used at lower pressures. What

may be regarded as a standard catalyst consists of a carefully purified magnetic oxide of iron, doubly promoted with oxides of aluminum and potassium in small percentages (1).

#### Ammonia Recovery and Gas Purge.

These two topics are closely interrelated, as will be seen in Figure 1. Materials are withdrawn from the system at three points, designated as *R*, *S* and *Q* on the flow diagram. In each case, a mixture of ammonia and gas is withdrawn. The separator underflows are predominantly liquid ammonia with some dissolved gas, and the separator top flows are predominantly gas with varying proportions of ammonia. The main separators, from which streams *R* and *S* are withdrawn, account for most of the ammonia recovery, while the purge point *Q* serves to complete the necessary elimination of inerts, beyond the relatively small amount of uncontrolled purging.

In synthesis operation near 1000 atm., satisfactory ammonia condensation and recovery are effected by cooling the freshly converted gas streams to temperatures attainable with ordinary cooling water. Complete elimination of ammonia from the gas stream after each conversion pass is not essential nor is it particularly desirable. At least one type of synthesis system, the Casale, is said to be designed deliberately so as to retain a certain minimum ammonia content in the recycled gas (3), the purpose being to utilize the repressive effect of residual ammonia on the initial rate of reaction to avoid hot spots where the incoming gas first meets the catalyst. Residual ammonia concentrations of 4 to 6 per cent are common both for 1000 atm. and lower-pressure systems.

In Figure 1, the recovery of ammonia shown in the separator following converter *A* is about 80% and in converter *B*, 55%, of the ammonia in the incoming gas stream. The recovery following converter *B* is lower because the converted gas is diluted with make-up gas.

Liquid level in the main separators is controlled by the dip-legs shown as dotted lines in the separators. The dip-leg offtake valve is left slightly open and the underflow valve adjusted so as to maintain a continuous flow of mixed liquid ammonia and gas through the dip-leg. When the underflow is properly adjusted, so that ammonia is discharged at precisely the rate collected, the dip-leg offtake is cool (e.g., 40° to 50° F.). If the liquid level rises in the separator, the overflow stream is immediately warmer, since only liquid, at a temperature of about 75° to 85° F., will then be discharged. A drop in liquid level causes gas alone to flow overhead, and this results in a sudden temperature

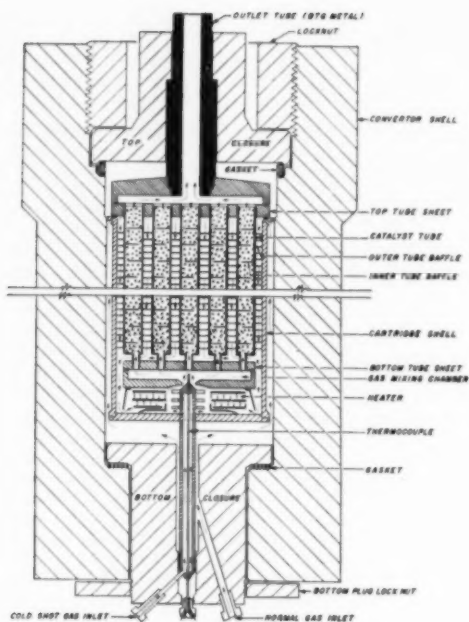


Fig. 2. Diagram of cross section of converter.

drop, accompanied by frosting of the line. Adjustment of the underflow valve to maintain the overflow temperature within a predetermined range therefore assures ammonia removal at the proper rate. Separator capacity above the dipleg represents several minutes' supply of the total ammonia collected, so that ample time is afforded for adjustment.

The amount of gas purged in this method of controlling separator liquid level just described is small compared with the total purge, as will be seen from the flow rates in Figure 1. All the streams *R*, *S*, and *Q*, which are expanded to lower pressures, are passed first through expansion coils. These are helices of fine-bore tubing, and serve to dissipate most of the energy of expansion. Combined with proper pressure gages, they also help to control flows.

The basic control for the remaining gas purge, at point *Q*, is total system pressure. In practice, the system is purged continuously at a substantially constant rate. This rate is reduced if necessary to offset a trend toward dropping pressure, and increased to counteract rising pressure. Other factors such as catalyst age, periodic determinations of the composition and quantity of the total purge, and production rate, also are taken into account in setting the purge rate. Purge stream *Q* is treated

for recovery of liquid ammonia in a manner similar to the condensation and separation to which the recycled gas is subjected, except that the cooled purge gas passes from the small separator directly to the purge gas manifold. (Gas issuing from the top of the main separators passes first through the ammonia receivers where the entrained liquid is deposited). Ammonia in the combined purge gas is absorbed in water under moderate pressure, then recovered as liquid ammonia by stripping and condensation, all by conventional means. The ammonia-free purge gas is suitable for use as fuel. It is sometimes sent to a liquefaction unit to remove the inert gases before returning the hydrogen-nitrogen mixture to the synthesis system. Recovery of argon in the liquefaction unit also is possible.

In Figure 1, the ammonia-free purge gas contains about 6% of the useful gas (i.e.,  $H_2$  and  $N_2$ ) fed to the system after methanation, which represents an overall conversion efficiency of 94%. This may be compared with conversion efficiencies of 96% to 97% observed by Brown and Cline for a 300-atm. synthesis system (2). It should be remarked, however, that many Claude units now in use operate satisfactorily with inerts concentrations of 25% or higher in the circulatory synthesis sys-

tem, compared with the 20% used in the present illustration. Actually, methane is regarded as having something of a beneficial effect on the system; it tends to dampen the ammonia reaction and therefore to assist indirectly in heat transfer, smoothing the operation, and control of the system. The net loss through purging decreases with increased inerts concentration: for example, if the gas at *X* contained 25% ( $CH_4 + A$ ), other things being equal, the calculated purge loss would drop to about 5%. Similarly, the proportion of the ammonia that is recovered in the aqua form drops as inerts concentration is increased. In Figure 1, about 7% of the total ammonia is shown as leaving with purge stream *X*. This would drop to 5% if the inerts concentration were allowed to reach 25%.

**Chemical Control.** Claude synthesis units ordinarily do not require 24-hr. duty in the chemical control laboratory. As noted previously, maintenance of a constant hydrogen concentration in the feed gas to the methanator assures the proper  $H_2/N_2$  ratio for synthesis; this concentration is indicated and recorded automatically by a thermal conductivity instrument. Operators make regular titrations of the dilute aqua ammonia condensed after methanation, without leaving the operating area, and control methanation on the basis of the results. This contrasts with the practically continuous laboratory analysis and chemical adjustments required for control of a copper-liquor system for carbon monoxide removal.

A hydrogen-analyzing instrument also indicates and records the concentration in the circulating gas stream. This analytical information together with indicated or recorded temperatures, pressures, gas flows and ammonia-recovery rates, is sufficient for hour-by-hour control of the unit. Day-shift gas analyses serve to check the recording instruments and supplement the data on hydrogen concentrations with one or more daily determinations of the other gas constituents. Product analyses also are made only on the day shift. Ammonia quality usually is high. For example, most Claude ammonia is suitable after degasification for use in ammonia oxidation, and in refrigeration systems, both of which uses require high purity.

### Apparatus and Equipment

The heart of any synthesis system is the synthesis converter itself. The converter design currently provided for Claude plants is, in many respects, similar to those that have been described previously for other synthesis systems operating at similar or lower pressures (3). Essential details of the Claude-converter design are illustrated

in Figure 2, which is a diagrammatic sketch of an ammonia converter cross section. The methanation converter is similar in design.

The converter shell is a thick-walled carbon steel cylinder with top and bottom closures. A basket, or cartridge, containing heat-exchange tubes and catalyst fits inside the shell, occupying most of its length. Electric heating coils for start-up and temperature control also are part of the cartridge assembly. The cartridge is an integral unit which may be lifted from the shell by removing the top closure and breaking minor connections at the bottom.

The main stream of incoming cold gas enters through an opening in the bottom closure, passes around the closed bottom of the cartridge and upward through a narrow annulus between the shell and the cartridge wall, which is wrapped on the outside with an insulating material. The cold gas controls the shell wall temperature, so that it ordinarily does not exceed 120° F. This gas enters the body of the cartridge through radial holes drilled in the cartridge wall at the top. The catalyst tubes are closely spaced in concentric circles inside the cartridge. These tubes are open at the top, where they are attached to the tube sheet. The tubes are plugged at the bottom and each plug is drilled to take an adapter nipple of smaller bore than the tube. The adapter thus projects downward from the plug. These adapters fit into a bottom tube sheet, whose outside diameter is slightly less than the inside diameter of the cartridge wall, so that space is left for downward flow of gas around the bottom tube sheet. A short gas-mixing chamber is provided just below the bottom tube sheet.

Full-disk baffles drilled to fit snugly around the outside of the tubes direct the downward flow of fresh cold gas entering at the top of the cartridge. Small slots are cut through the baffles at the periphery of the tube walls and the gas passes downward through these slots. The slot positions are staggered from baffle to baffle and the gas thus is forced into highly turbulent flow which is concentrated at the tube walls. Preheated gas passing through the bottom baffle goes around the bottom tube sheet and into the gas-mixing chamber where it meets a by-pass stream of (usually) cold gas.

The freshly converted gas rising from the catalyst hot zone loses heat to the incoming cold gas; by the time it leaves the tubes its temperature has been reduced so that its sensible heat gain closely approximates the heat of reaction. The operation therefore is essentially autothermal. The necessary outlet gas temperature for autothermality is readily calculable from knowledge of recirculation rates and ammonia concentrations, and this outlet temperature is an important control point. The thermocouple in the gas-mixing chamber, which measures temperature of the inlet gas mixture, also is important in controlling the operation. The upward gas flow through the catalyst is directed by circular segmental baffles which are inserted as the catalyst is charged into the tubes.

The gas issuing from the top of the catalyst tubes is collected in a cover over the top tube sheet, whence it passes through the outlet tube to the precooler shown in Figure 1. The outlet tube and a short length of piping up to the cooler are made of BTG metal, which is an alloy of nickel, chromium and iron, with some tungsten. BTG metal is particularly adapted to withstanding hydrogen attack at high pressure and elevated temperatures. Its yield point remains high at elevated temperatures. In the

present Claude design it is used only where the combination of high pressure and temperature is unavoidable. The only pieces of BTG equipment besides those just named are the tube bottom plugs and the thermocouple well.

In the early stages of the Claude development, before the circulatory-synthesis system and the heat-interchange technique described herein were adopted, the entire converter body, and certain other parts, were made of BTG metal. This extensive use of the metal was abandoned several years ago. Less expensive alloy steels are used in other minor pieces such as the methanator catalyst tubes, top tube sheet, and cartridge cover, which must withstand carbon monoxide attack, and copper is used for the disk baffles in the cartridges. However, by far the predominant weight of piping, valves, converters, separators, and other high-pressure equipment is in carbon steel.

It is the practice of the French designers to locate methanators and converters in a concrete structure open on only one side, this side facing away from other equipment and buildings. Separators are mounted in the open between this structure and a concrete wall, behind which the operators are stationed. Stems of the principal control valves extend through this wall to a control board, and substantially all of the routine operating adjustments are made from the board itself. The valves are not unusual in design and are easily operated by hand. Part of the precautions are admittedly holdovers from the early stages of the development when imperfect temperature control resulted in some failures of equipment under pressure. Failures of this sort have not occurred within the past 25 years. Another safety precaution is to install at least two valves in series on all important lines to permit "double-blocking" when workmen are engaged in maintenance or adjustments nearby.

One experienced operator per shift is sufficient for operation of a Claude unit such as described herein, including the final purification by methanation. Adjustments in gas-flow rates are made at the board as dictated by temperature and pressure conditions, ammonia production rate, and the periodic titrations of condensate from the methanator. The necessity for a catalyst change is indicated by a small gradual drop in production rate and by a gradual increase in the pressure required to maintain a constant production (as mentioned earlier, the operating pressure at start-up and for some weeks thereafter is frequently less than the 15,000 lb./sq.in. shown in Fig. 1). This occurs during perhaps the last third of an operating period, and the change is

scheduled for a convenient time. In the system of Figure 1 either converter may be changed while the other remains in operation. Both units are shut down together when methanator catalyst is changed, which is about every other converter change.

Completely assembled spare cartridges are kept on hand for catalyst changes. After a reactor has been shut down and depressurized, the head is removed, the necessary bottom connections broken, and the cartridge containing the spent catalyst is lifted out. It is immediately replaced by a fresh cartridge, the reactor is repressured, and reduction is started. Spent catalyst is dumped out of the cartridge, which is inspected and any necessary repairs are made before charging it with fresh catalyst. Cartridge life is six to eight years. Reactor shells last indefinitely.

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## Discussion

**Lawrence Lynn** (Celanese Corp. of America, Clarkwood, Tex.): You mentioned that the total amount converted was 65%. Can you tell me what fraction of this conversion occurred in the first converter and what in the second?

**H. L. Thompson:** About 40% and 25%.

**Lawrence Lynn:** Is there any Claude process plant on stream in the U. S. at the present time?

**H. L. Thompson:** Yes, there are two, actually—one at Hercules, Calif., and one at Houston, Tex.

**Lawrence Lynn:** How long have they been on stream?

**H. L. Thompson:** The Hercules plant has been operating since 1939, I believe. The plant near Houston was completed in 1942 and operated for a good while at Louisiana, Mo. It was moved to Houston after the war, so I'd say its total operating time has been some four or five years.

**Lawrence Lynn:** We've heard a good deal about the possibility of hydrogen destruction of the carbon structure of steel at over 10,000 lb./sq.in. pressure and I wonder if within your experience you have noted this phenomenon. Does your reactor exhibit carbon steel des-

truction by hydrogen and what do you do to lessen it?

**H. L. Thompson:** In connection with our studies of the Claude system, representatives of our company have visited eight of the Claude units now in operation and found no indication such as you mention, in the converter shell itself—the shell that withstands the pressure. I think the reason is that the temperature is kept so low in the shell itself. The shell temperature is kept below 120° F. and I believe the first shell put in by the Claude firm is still in operation.

(Presented at A.I.Ch.E. Kansas City (Mo.) Meeting.)

## ABSTRACTS

Abstracts of papers published in "Phase-Equilibria—Minneapolis and Columbus," Chemical Engineering Progress Symposium Series No. 3, Vol. 48 (1952). The volume may be ordered from Chemical Engineering Progress, 120 East 41 Street, New York 17, New York.\*

### SOLUBILITY RELATIONS OF FLUOROCARBONS

Joel H. Hildebrand  
University of California

**P**HASE-equilibria involving fluorocarbons may be predicted to a degree of accuracy sufficient for most practical purposes. When an exceptionally good or an exceptionally poor nonpolar solvent is demanded, these substances offer attractive possibilities. The theory is outlined, and in the light of it a number of phase-equilibria involving fluorocarbons are analyzed.

*Chem. Eng. Progress Symposium Series—"Phase-Equilibria—Minneapolis and Columbus," 48, No. 3, 3 (1952).*

### PHASE-EQUILIBRIA AT HIGH PRESSURES—THE SYSTEM: NITROGEN-AMMONIA AT PRESSURES ABOVE 1000 ATM.

Arthur E. Lindroos and Barnett F. Dodge  
Yale University

**T**HIS investigation of the phase behavior of the binary system ammonia-nitrogen covers the pressure range of 1000 to 3750 atm. and the temperature range of

30° to 110° C. At 85° C. and below, two phases are present at all pressures investigated; at 90° C. and above, the two-phase region does not extend throughout the entire pressure range. The type of phase behavior in these experiments differs widely from the usual vapor-liquid equilibrium and has been designated gas-gas or fluid-fluid equilibrium.

*Chem. Eng. Progress Symposium Series—"Phase-Equilibria—Minneapolis and Columbus," 48, No. 3, 10 (1952).*

### PHASE-EQUILIBRIA IN THE ACETONE-METHANOL-WATER SYSTEM FROM 100° C. INTO THE CRITICAL REGION

John Griswold and S. Y. Wong  
Illinois Institute of Technology and  
University of Texas

**B**INARY and ternary  $y$ - $x$ - $P$ - $T$  data on acetone, methanol, and water mixtures have been determined as isotherms to 200° and 250° C. The critical compositions of the aqueous binaries and the critical composition locus of the ternary were determined at this temperature. Ternary isotherms were determined at 100° and 250° C. and several ternary determinations were made

at 150° and 200° C. These data were interpolated by means of activity coefficients to construct complete isotherms for the two intermediate temperatures.

*Chem. Eng. Progress Symposium Series—"Phase-Equilibria—Minneapolis and Columbus," 48, No. 8, 18 (1952).*

### GRAPHICAL TECHNIQUES FOR RECIPROCAL SALT-PAIR SYSTEMS

Henry B. Suhr

American Potash and Chemical Corporation

**A** MODIFIED method of representation is presented from which useful two-dimensional projections of four or more compounds comprising reciprocal pairs may be derived. This method simplifies the graphical analysis of phase reactions and is illustrated with isothermal diagrams of the quaternary system  $KCl$ - $NaCl$ - $K_2SO_4$ - $Na_2SO_4$ - $H_2O$ .

*Chem. Eng. Progress Symposium Series—"Phase-Equilibria—Minneapolis and Columbus," 48, No. 3, 35 (1952).*

\* See advertisement, page 32, News Section, for details.

## SOLVENT EXTRACTION FROM AQUEOUS SOLUTION—EFFECT OF ADDITION OF INORGANIC SALTS

I. E. Swabb, Jr., and E. L. Mangan  
University of Cincinnati

**I**N a process which extracts a valuable compound from an aqueous solution, the addition of an inorganic salt improves the equilibrium relations, favoring the extraction of the desired compound. For the design of such processes, solubility relationships in systems of the type water, organic solvent, consolute material, and inorganic salt have been correlated by means of the Setschenow equation. Data for the system water, isopropyl ether, acetic acid, sodium sulfate are presented to substantiate this conclusion. The proportional change in consolute distribution caused by the addition of salt is the same no matter what the solvent phase may be.

*Chem. Eng. Progress Symposium Series—“Phase-Equilibria—Minneapolis and Columbus,”* 48, No. 3, 40 (1952).

## EQUILIBRIUM CONDITIONS OF FLASH VAPORIZATION OF PETROLEUM FRACTIONS

Wayne C. Edmister and John R. Bowman  
Carnegie Institution of Technology  
and Mellon Institute

**A** PROCEDURE and charts are presented for estimating the temperature-pressure condition for equilibrium flash vaporization of petroleum fractions. The charts include a plot of  $K_f$  (equilibrium vapor-liquid distribution ratio for the reference component) vs. temperature and pressure; a graphical solution of the equations relating  $K_f$  with terminal relative volatilities and fraction flashed; and a method for converting results obtained in liquid-volume fractions to mole fractions and vice versa.

*Chem. Eng. Progress Symposium Series—“Phase-Equilibria—Minneapolis and Columbus,”* 48, No. 3, 46 (1952).

## ISOBARIC LIQUID-VAPOR EQUILIBRIUM CALCULATIONS

Melvin Nord  
Wayne University

**V**ARIOUS thermodynamic formulas for isobaric liquid-vapor equilibrium are presented and their applicability and limitations discussed. The necessity, in nonregular solutions, for experimental data to determine the variation of activity coefficients with temperature is considered. The use of semiempirical equations such as the Van Laar and Margules equations and modified versions of these is noted, and methods for determining the constants in these equations are recommended.

*Chem. Eng. Progress Symposium Series—“Phase-Equilibria—Minneapolis and Columbus,”* 48, No. 3, 55 (1952).

## P-V-T-X RELATIONSHIP FOR THE SYSTEM METHANE-ISOPENTANE

Erwin H. Amick, Jr., Winford B. Johnson,  
and Barnett F. Dodge  
Yale University

**F**IVE mixtures containing from 15 to 80 mole % methane, respectively, were investigated over a temperature range from

30° to 200° C. and a pressure range from 90 to 1500 lb./sq.in. abs. The variable-volume method of experimentation was used, and the results are presented in four tables: (1) compressibility factor as a function of pressure, (2) saturated-vapor volumes, (3) saturated-liquid volumes, and (4) critical data. Equilibrium vaporization ratios  $K$  were calculated from the data, and comparisons were made with the predictions of generalizations in common use.

*Chem. Eng. Progress Symposium Series—“Phase-Equilibria—Minneapolis and Columbus,”* 48, No. 3, 65 (1952).

## P-V-T-X RELATIONS OF THE TOLUENE-N-HEXANE SYSTEM

Lloyd M. Watson and Barnett F. Dodge  
Yale University

**V**OLUMETRIC and phase behavior of three mixtures of toluene and n-hexane were investigated in the temperature range from 225° to 300° C., and in the pressure range from 13 to 95 atm. Volume data for superheated n-hexane from 250° to 300° C. are given for the same pressure range, and data for toluene are given from 250° to 300° C. and for the pressure range from 10 atm. to the dew point. Equilibrium vaporization ratios  $K$  were calculated and compared with predicted values.

*Chem. Eng. Progress Symposium Series—“Phase-Equilibria—Minneapolis and Columbus,”* 48, No. 3, 72 (1952).

## VAPORIZATION EQUILIBRIA OF METHANE AT HIGH PRESSURES

J. Howard Arnold  
California Research Corporation

**A** NEW and simple empirical graphical correlation in terms of composition and convergence points is presented, for methane-in-solvent systems only, and applied to published data for methane in crude oil, absorption oil, and gas distillate, as well as in binary systems. The graphical method of Mayfield for estimating critical loci of paraffin mixtures is modified and reduced to analytical form for more convenient use.

*Chem. Eng. Progress Symposium Series—“Phase-Equilibria—Minneapolis and Columbus,”* 48, No. 3, 82 (1952).

## LIQUID-VAPOR EQUILIBRIUM IN LIGHT-HYDROCARBON—ABSORBER-OIL SYSTEMS

Ernest Solomon  
The M. W. Kellogg Company

**L**IQUID-vapor equilibrium data have been obtained on mixtures of methane-ethylene-isobutane with each of the following nonvolatile absorber oils: n-hexadecane, dicyclopentyl, methylnaphthalene, midcontinent virgin gas oil, and hydroformer still bottoms. The data have been used to establish a method for predicting the  $K$  values of light hydrocarbons in ab-

sorber-oil systems. A correction factor based on the aromaticity of the liquid phase is applied to Kellogg  $K$  values derived from the Kellogg equation of state.

*Chem. Eng. Progress Symposium Series—“Phase-Equilibria—Minneapolis and Columbus,”* 48, No. 3, 93 (1952).

## VAPOR-PRESSURE-TEMPERATURE CORRELATIONS FOR HYDROGEN MIXTURES IN BATCH DIFFERENTIAL VACUUM DISTILLATION

George G. Lamb and Ivan J. Sitar  
Northwestern University

**S**IMPLE batch differential vacuum distillations of multicomponent hydrocarbon mixtures are of more value if a sound procedure is available for correcting the distillation curves from one pressure to another. Theoretical equations have been developed to permit calculating distillation curves for hydrocarbon mixtures at pressures from 1 to 760 mm. of mercury. A modified Cox chart permits straight-line interpolation and extrapolation of data.

*Chem. Eng. Progress Symposium Series—“Phase-Equilibria—Minneapolis and Columbus,”* 48, No. 3, 99 (1952).

## LIQUID-VAPOR EQUILIBRIUM RELATIONS IN BINARY SYSTEMS: THE ETHANE BENZENE SYSTEM

W. B. Kay and T. D. Nevins  
Ohio State University

**T**HE  $P$ - $V$ - $T$ - $X$  relations at the vapor-liquid phase boundaries for the system ethane-benzene were obtained from measurements of a series of mixtures varying in composition from pure ethane to pure benzene and covering a temperature range from 32° to 552° F. and a pressure range from 200 to 1428 lb./sq.in. gage.  $P$ - $X$ ,  $T$ - $X$ , and density-temperature diagrams were constructed for a series of pressures, temperatures, and compositions, and the vapor-liquid equilibrium ratios were calculated. A comparison was made of the equilibrium ratios for ethane dissolved in n-heptane, n-butane, and benzene.

*Chem. Eng. Progress Symposium Series—“Phase-Equilibria—Minneapolis and Columbus,”* 48, No. 3, 108 (1952).

## VAPOR-LIQUID EQUILIBRIUM IN THE BINARY SYSTEM HYDRAZINE AND WATER

R. Q. Wilson, H. P. Munger, and J. W. Clegg  
Battelle Memorial Institute

**T**HE vapor-liquid compositions for the binary system hydrazine and water were determined at atmospheric pressure. The maximum boiling azeotrope boiled at 120.1° C. and had a composition of 70 weight % hydrazine. The compositions were determined at 25 points on both sides of the azeotrope.

*Chem. Eng. Progress Symposium Series—“Phase-Equilibria—Minneapolis and Columbus,”* 48, No. 3, 115 (1952).

# PLASTICS EQUIPMENT REFERENCE SHEET

RAYMOND B. SEYMOUR and ROBERT H. STEINER

The Atlas Mineral Products Co., Mertztown, Pa.

**POLYETHYLENE:** Unfilled, unplasticized, flexible polyethylene plastic is available in the form of sheets up to 1/2 in. thick, rod and pipe up to 6-in. diam., and custom-made valves, fittings, tank linings, bottles, etc.

dered poly-ethylene can also be flame-sprayed on metallic surfaces, injection molded, calendered and extruded.

**CHEMICAL COMPOSITION:** Practically 100% stabilized polyethylene, pig-

mented material also available.

**MACHINABILITY:** Can be cut, drilled, turned, blanked, punched, routed and sanded on ordinary woodworking equipment. Because of its thermoplasticity, cooling is required in many operations.

**TEMPERATURE LIMITATIONS:** Not recommended for use above 125° F.

**APPLICATION AND REMARKS:** Sheets can be heat-formed drawn, blow-molded or hot gas-welded to form semi-rigid structures. Pow-

## MECHANICAL AND PHYSICAL PROPERTIES:

Tensile Strength, lb./sq.in. @ 750° F.	1,300-1,750
Elongation, %	200%
Specific Gravity	0.92
Modulus of Elasticity in tension (x 10 <sup>4</sup> lb./sq.in.)	1.9
Impact Strength	Does not break
Compressive Strength	Does not fracture
Flexural Strength, lb./sq.in.	1,700
Hardness (Rockwell)	R 11
Thermal Conductivity (x 10 <sup>-4</sup> B.t.u./ (sec.) (sq.ft.) (1° F.)/in.)	6.4
Specific Heat (B.t.u./ (lb.) (° F.)	0.55
Thermal Expansion (x 10 <sup>-5</sup> ° F.)	9-10
Heat Distortion Temperature (° F.)	107 (66 lb./sq.in. load)
Volume Resistivity	> 10 <sup>15</sup> ohm-cm.
Flammability	Burns slowly

## CHEMICAL RESISTANCE

	75° F.	125° F.		75° F.	125° F.		75° F.	125° F.
<b>ACIDS</b>			<b>ACID SALTS</b>			<b>Refinery Crudes</b>		
Acetic, 10%	E	E	Alum or Aluminum Sulfate	E	E	Trichloroethylene	N	N
Acetic, glacial	E	N	Ammonium chloride, nitrate, sulfate	E	E	<b>PAPER MILL APPLICATIONS</b>		
Benzene sulfonic, 10%	E	E	Copper chloride, sulfate	E	E	Kraft Liquor	E	E
Boric	E	E	Ferric chloride, sulfate	E	E	Black Liquor	E	E
Butyric	N	N	Nickel chloride, sulfate	E	E	Green Liquor	E	E
Chloroacetic	E	E	Stannic chloride	E	E	White Liquor	E	E
Chromic, 10%	E	E	Zinc chloride, sulfate	E	E	Sulfite Liquor	E	E
Chromic, 50%	E	E	<b>ALKALINE SALTS</b>			Chlorite Bleach	E	E
Citric	E	E	Barium sulfide	E	E	Alum	E	E
Fatty Acids (> C <sub>8</sub> )	E	E	Sodium bicarbonate	E	E	<b>PHOTOGRAPHIC INDUSTRY</b>		
Fluosilicic	E	E	Sodium carbonate	E	E	Developers	E	E
Formic, 90%	E	F	Sodium chloride	E	E	General Use	E	E
Hydrobromic, 40%	E	E	Sodium sulfide	E	E	Silver Nitrate	E	E
Hydrochloric, 37%	E	E	Trisodium phosphate	E	E	<b>FERTILIZER INDUSTRY</b>		
Hydrocyanic	E	E	<b>NEUTRAL SALTS</b>			General Use	E	E
Hydrofluoric	E	E	Calcium chloride, sulfate	E	E	<b>STEEL</b>		
Hypochlorous	E	E	Magnesium chloride, sulfate	E	E	Sulfuric Acid Pickling	E	G
Lactic	E	E	Potassium chloride, sulfate	E	E	Hydrochloric Acid Pickling	E	G
Maleic	E	E	Sodium chloride, sulfate	E	E	Sulfuric Acid-Nitric Acid Pickling	E	F
Nitric, 5%	E	E	<b>GASES</b>			<b>TEXTILES</b>		
Nitric, 20%	E	E	Chlorine, dry	P	N	General Use	E	E
Nitric, 40%	E	G	Chlorine, wet	N	N	<b>FOOD</b>		
Oleic	P	N	Sulfur dioxide, dry or wet	E	E	General Use	E	E
Oxalic	E	E	<b>ORGANIC MATERIALS</b>			Breweries	E	E
Perchloric	E	E	Acetone	P	N	Dairies	E	E
Phosphoric, 85%	E	E	Alcohol, methyl or ethyl	N	N	<b>MISCELLANEOUS INDUSTRIES</b>		
Picric	E	E	Aniline	N	N	Plating	E	F
Stearic	P	E	Benzene	N	N	Petroleum	P	N
Sulfuric, 50%	E	E	Carbon Tetrachloride	N	N	Tanneries	E	E
Sulfuric, 70%	E	F	Chloroform	N	N	Oil and Soap	F	N
Sulfuric, 93%	F	N	Ethyl Acetate	P	N	Water and Sewer	E	E
oleum	N	N	Ethylene Chloride	N	N			
Mixed Acids: 57% H <sub>2</sub> SO <sub>4</sub> , 20% HNO <sub>3</sub>	E	E	Formaldehyde, 37%	E	E			
			Phenol, 5%	E	G			
<b>ALKALIES</b>								
Ammonium Hydroxide	E	E						
Calcium Hydroxide	E	E						
Potassium Hydroxide	E	E						
Sodium Hydroxide	E	E						

### RATINGS:

E—No attack.  
G—Appreciably no attack.  
F—Same attack but usable in some instances.  
P—Attacked—not recommended.  
N—Ridly attacked.

**No. 13**

(IN A SERIES ON CORROSION RESISTANT MATERIALS)

# NEWS SECTION

## MANPOWER IN CHEMICAL ENGINEERING

A STUDY entitled "Manpower Resources in Chemistry and Chemical Engineering, 1951," will soon be off the press as Scientific Manpower Series No. 4 of the National Scientific Register. The study reports on a questionnaire survey, made early in 1951, with the cooperation of the American Chemical Society. The Bureau of Labor Statistics, U. S. Department of Labor under contract with the National Scientific Register, edited and coded the questionnaires. A few of the preliminary findings are reported here.

The report covers much familiar territory, adding, in many cases, data which will round out studies that have already been made. All in all, 13,342 chemical engineers answered the question, though these comprised a miscellaneous group, containing non-members of scientific societies as well as some members. The nucleus of the survey was the A.C.S. membership list and the A.C.S. member prospect list. First, the survey showed only a small percentage of the chemical engineers, about 0.3%, to be women, in contrast to a 7% proportion among chemists. The median age of the chemical engineers in this survey is younger than that of chemists by about three years, chemical engineers having a median age of thirty-two years. This checks closely with most previous surveys made on chemical engineers, including that published in the August issue of Chemical Engineering Progress. Similarly the chemical engineers were found to be 96% native born. One out of every four chemical engineers is in the military reserve in one branch or another; 10% of the chemical engineers under twenty-six are on active duty with the armed forces, and out of the 261 chemical engineers found to be in the armed services at the time of the survey, only sixty-nine reported that they were doing scientific work.

Among the chemical engineers, the level of education was 71% bachelor's degrees; master's degree 20%; and only 7% of the engineers held Ph.D.s. It is interesting to note that a previous study, "The Engineering Profession in Transition" (1946) found 12.7% of the chemical engineers had Ph.D.s., and this was checked by the survey published last

month in "C.E.P."

One of the important findings of the new study is that few entered the chemical engineering profession from other fields of study. Only 3% of the chemical engineers of the survey held their highest degrees in a subject other than chemical engineering. There was some shifting at the Ph.D. level from chemistry to chemical engineering, but on the whole, few men are coming into the profession from disciplines other than chemical engineering.

The fields in which chemical engineers are employed have changed little since the "Transition" survey was made for the Engineers' Council for Professional Development in 1946. Table 1 shows the change since 1946, and reveals that chemical and allied products, as well as petroleum and coal products, seem to be getting more than a proportional share of the larger group of chemical engineers.

### Function

According to this survey, the largest single function of the chemical engineer was in research and development with the next largest being production. However, this study found out that only 10% of the engineers were in management,

the lowest of any survey yet. It also reports that 27.6% of the chemical engineers were in production, which is more than double results previously reported in other studies.

Table 2 shows the variations in occupation as found by four different surveys, and points up the need for definitive job descriptions in any future questionnaires of this sort.

### Income

As far as income was concerned after all the data were tabulated the chemical engineers are credited with a median annual income of \$5,600 in mid-1951. The lower quartile was \$4,400, with the upper quartile \$7,300.

(Editor's Note: This salary median is low in comparison with A.I.Ch.E. experience for the following reason: In 1946, the publication "The Engineering Profession in Transition" showed a median salary of A.I.Ch.E. members for the age bracket 32-34 as \$5,300. An age bracket raise of only \$300 in the past five years seems small. Further, a survey in 1949 by the National Scientific Register, in cooperation with the A.I.Ch.E. and E.J.C., of the Institute Active members showed for the age bracket 35-39 that chemical engineers had a median income of \$7,600. The present study on which we are here reporting finds a median income for that age group as \$7,300, or a loss of \$300 in two years. That the data are correct for both studies we have no doubt; the

(Continued on page 30)

TABLE 1.

Industry	Per cent employed in 1951	Per cent employed in 1946
All manufacturing	100.0	100.0
Food and textiles	5.1	6.3
Lumber, furniture and paper	3.6	4.8
Printing and publishing	0.2	1.6
Chemicals and allied products	48.3	42.1
Petroleum and coal products	21.2	25.1
Rubber, stone, clay, and glass	4.1	7.6
Iron, steel, and nonferrous metals	2.0	4.1
Machinery (incl. electrical)	6.9	3.2
Transportation equipment	0.8	1.2
Other manufacturing	7.8	4.0

TABLE 2.

	1952* Per Cent	1951† Per Cent	1951‡ Per Cent	1946§ Per Cent
Research and development	34	30.5	36.0	30.4
Consultants	1	4.0	---	3.9
Management	21	10.1	11.6	31.8
Teaching	3	3.2	4.9	5.0
Technical writing	2.5	0.6	---	---
Design	15	12.5	11.0	10
Inspection and testing	---	5.6	3.6	---
Production	12	27.6	14.8	5.1
Technical sales	6	2.8	5.2	2.3
Other	8	2.1	---	---

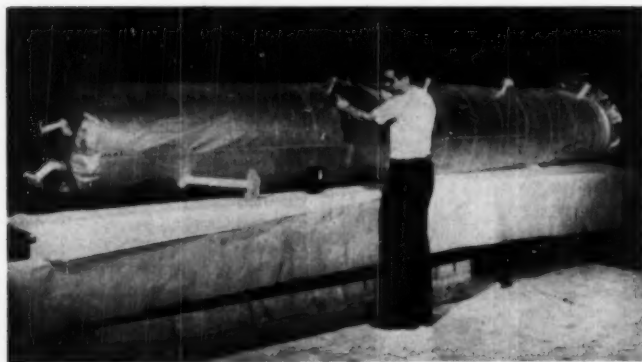
\* Chemical Engineering Progress, August, 1952.

† Scientific Manpower Series 24.

‡ U. S. Department of Labor, Bureau of Labor Statistics, Employment, Education and Income of Engineers, 1949-50 (in process of publication). A.I.Ch.E. Active member only.

§ The Engineer in Transition.

## LINER FOR FRACTIONATING TOWER



A fractionating tower liner for handling hydrofluoric acid made entirely from Kel-F, fluoro-chloro-carbon thermoplastic, was recently fabricated by Electronic Wave Products, Inc. When in use, the liner will guard a tower which, if unprotected, would require replacing at regular intervals, due to unpreventable seepage of corrosives through the mortar joining the brick lining. The plastic "vessel" was fabricated from extruded film 0.005 in. thick. The film was electronically fused by high frequency to form the 18-ft. long, 3-ft. diam. closed cylinder. Two layers were laminated to give the liner greater strength and provide greater protection against the possibility of damage. All nozzles were also formed from the film, although a heavier gage was employed.

In the photograph, one of Electronic Wave's technicians is electronically checking the liner for possible porosity or pinholes. To keep it in this expanded condition and still not place any stress upon the seams, a bag made of vinyl was inserted and then inflated.

## LIVE CORNERSTONE AT CENTENNIAL

Chicago's Museum of Science and Industry dedicated a "living" cornerstone Sept. 3, at the opening-day ceremonies of the two-week convocation of the Centennial of Engineering. Although the building dates back to 1893 when it was erected for the World's Columbian Exposition, the cornerstone was never laid.

Commemorating 100 years of American engineering achievements, the cornerstone was set in place in a simple ceremony. Lenox R. Lohr, president, and D. M. MacMaster, director of the Museum, officiated.

Where traditional cornerstones are concerned with the history and memories of the past, the Museum stone was dedicated to the future. Everything in the cornerstone was physically or biologically "alive," symbolizing the Museum's concern with present accomplishments and the promise of the future. Marking the present atomic age of discovery, some of the stone's contents were radioactive, pulsing with the atomic life that holds promise for the engineers and scientists of tomorrow. A specially constructed "clock" will count off not seconds or minutes but years inside the cornerstone.

In the heart of the 1-ton granite block a monel metal box was carefully fabricated wherein, surrounded by an inert

gas, helium, a number of laboratory experiments were designed to prove or disprove some of today's theories in an experiment that will last 100 years.

Among the contents were small amounts of dry hydrogen and oxygen in the proper proportions to form water which will react slowly because of the absence of any catalyst.

In another sealed capsule were Oriental lotus seeds, traditionally associated with longevity. When that section of the box is opened after a hundred years have passed, scientists will have accurate data on ability of seed to maintain germination qualities.

The Museum's purpose in dedicating the "laboratory" of its cornerstone is to provide the opportunity of conducting long-time experiments. The tests were determined by a group of scientists at the University of Chicago, and through consultation with other scientists.

An experiment in slow change was included in the field of crystallization. Under normal laboratory conditions it is impossible to make observations of this type for a long enough period; and if the experiment is speeded up a different crystalline structure will result.

Among the contents of the stone was a small lead block plated on one surface with a thin layer of a radioactive lead isotope (with a half-life of 22 years).

When the stone is opened scientists will be interested in determining to what depth the radioactivity of the isotope has penetrated or sunk in the block as well as in the amount of radioactivity still remaining in the material.

Varieties of biological molds, including the mold that is used to produce penicillin, were also placed in the stone. These will be in a state of suspended activity during their incarceration and after a hundred years they will be allowed to resume their biological activity if they have survived the test. Along the same lines, several kinds of virus and bacteria were similarly included to determine their longevity for the hundred-year period.

Counting off the years until the cornerstone is reopened there is a thermostat clock, especially constructed for the purpose. Designed on the same principle as the ordinary room thermostat to control temperature, the cornerstone's clock consists of two strips of metal that expand differently with temperature changes. Thus the thermostat is set to register once when Chicago's temperature passes 85° and then will not register again until the temperature has gone below 15°.

## POWDERED PHENOLICS MADE BY REICHOLD

Reichhold Chemicals, Inc., manufacturer of synthetic resins and producer of phenol, recently announced plans to manufacture and market powdered phenolics for a variety of industrial applications, including molding compounds, foundry shell molds and cores, brake linings, grinding wheels and wood waste products.

As a result of completion of expanded facilities at its Tuscaloosa, Ala., plant, Reichhold will produce annually 60,000,000 lb. of phenol according to P. J. Ryan, vice-president in charge of Reichhold's southern division. Completion of installation of new 10,000-gal. stainless steel kettles at RCI's Detroit and Elizabeth, N. J., plants as well as Tuscaloosa, also makes it possible to produce increased amounts of phenolic resins at these locations.

The Tuscaloosa plant was built during World War II solely for the manufacture of phenol, but research was initiated at that time for eventual expansion into the plastics field, according to Mr. Ryan.

With nineteen plants in foreign countries and ten in the United States, Reichhold Chemicals also plans to develop the use of powdered phenolics overseas as well as in this country. Harry Kline, vice-president in charge of phenolic plastics, declared.

# TYGON

Versus  
**NaOH**

**S**ODIUM hydroxide, by any name—"caustic," "caustic soda," "lye or soda lye"—is always a hard-to-handle chemical. But you can handle it—handle it with ease and safety—by calling on the versatile TYGON family of plastic compounds. TYGON, in any of its forms, through proper use, can help you cut corrosion costs—can increase your plant safety—can improve your factory housekeeping.

Basically, TYGON consists of a series of skillfully modified polyvinyl resins carefully compounded to give the best in chemical resistance and general physical properties. Each specific formulation of TYGON—each recommended use—results from decades of experience in corrosion control, and years of leadership in the use of vinyl resins to combat chemical attack.

As a calendared or press-polished sheet, TYGON can be used effectively to line tanks, drums, hoppers, bins, fume hoods, or fume ducts. The sheets can also be die-cut into gaskets, washers, and diaphragms for use as reliable, resilient seals or separators on all types of process equipment.

In tank lining or equivalent use, TYGON is resistant to caustic soda in concentrations up to 25% by weight and at temperatures as high as 150°F. As a gasket, or the like, TYGON resists all concentrations of caustic with temperature limits depending upon the design of the piece and the operating pressures involved.

In extruded form, TYGON is generally used as tubing or piping. However, the tubing, and extruded cord, channel, or tape, also finds use as gasketing, expansion jointing, packing, or wrapping.

TYGON Tubing is a familiar sight in the laboratory where its long life, full flexibility, transparency, and ease of use have put glass and other tubing in the background. The larger sizes, up to 2" ID, are likewise becoming commonplace in the plant for use as flexible piping in temporary or permanent transfer lines for both liquids and gases, as flexible connections, as inlet and outlet ports on pumps, filters and compressors, as syphon hoses, and as line desurgers. For pressure applications exceeding a constant head of 40 psi, particularly at elevated temperatures, braided jacket reinforcement is available and suggested. In all plant uses, the light weight, maneuverability, smooth surface, and abra-

sion resistance of TYGON Tubing add up to definite advantages over conventional piping.

Extruded, TYGON resists sodium hydroxide in any strength and at temperatures in the range of 150°-175°F. The temperature limit varies according to the wall thickness of the tubing, the use of braided reinforcement, the pressures involved, and whether or not the extrusion is supported or confined.

In molded form, TYGON exhibits approximately the same resistance as in the extruded form. Its uses are numerous and include application as gaskets, grommets, stoppers, closures, washers, bumpers, handles and special fittings. Where necessary, TYGON can be reinforced with glass fibers for added strength. Once again, specific temperature limits depend upon the size and design of the piece, the pressures involved and other conditions of service.

TYGON Paint, generally, sees service as a protective maintenance coating. As such, or in any paint application, the physical limits of a thin film must be realized. TYGON Paint provides excellent protection against the spillage or condensate of caustic soda in any concentration and at temperatures as high as 200°F. Prolonged immersion, however, is not recommended without the counsel of U. S. Stoneware engineers. In most cases, the minimum system recommended for caustic service consists of a primer and no less than five top coats.

As a plastisol (TYGOFLEX), TYGON finds application as a heavy duty coating and in the casting or "slush" molding of flexible parts and fittings. Against caustic soda, the resistance of TYGOFLEX depends primarily on the thickness of the coating deposited, but generally is greater than that of the paint film.

Regardless of the form in which it is used, TYGON provides an excellent means of protection against not only sodium hydroxide and other alkalies, but a wide range of acids, oils, greases and water. The different forms and compounds available and the range of properties they exhibit permit the proper use of TYGON in many applications. Versatility and satisfaction in service is further assured by the custom engineering, compounding, and fabricating services available from the plastics and corrosion experts at U. S. Stoneware.

In addition to TYGON in its various forms, we also manufacture a number of other materials capable of handling sodium hydroxide in various concentrations and under many types of operating conditions. These products include chemical stoneware and porcelain, acid proof brick and cements, and other organic linings and coatings. Why don't you submit your corrosion problem, today? There's no obligation and we'll be pleased to be of assistance. So write, now!

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20% Ni.  
1% Mo.



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For  
Defense  
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### MANPOWER

(Continued from page 27)

difference must come from the make-up of the groups surveyed, A.I.Ch.E. members having a higher income than non-members.)

The comparison of salaries found in this new study for chemists and chemical engineers is shown in Table 3.

TABLE 3.

	Chemists	Chemical Engineers
All Ages	\$5,500	\$5,600
Under 25	3,400	3,700
25-29	4,100	4,600
30-34	5,400	5,900
35-39	6,500	7,300
40-44	7,000	8,100
45-49	7,300	9,800
50-54	7,800	11,000
55-59	7,900	11,400
60-64	7,400	14,700
65 and over	6,800	19,000+

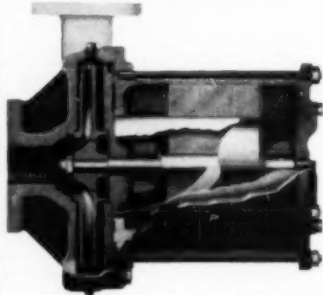
The salary of the engineers also varied according to the business field, and for chemical engineers, between the ages of 30-35, a median income is shown in Table 4 for various divisions in the chemical process field.

TABLE 4.

	Median Income
Food and kindred products	\$5,300
Paper and allied products	5,300
Chemicals and allied products	6,000
Stone, clay, and glass products	5,400
Primary metals	5,800
Machinery (except electrical)	5,900
Electrical machinery	5,400
Professional and scientific instruments	5,700
Petroleum refining	6,000
Engineering and consulting services	6,900

The study will be published shortly by the Bureau of Labor Statistics and Chemical Engineering Progress will carry a news item when copies are available from either the B.L.S. or the Federal Security Agency, Office of Education, Washington 25, D. C.

### MAGNETIC DRIVE PUMP



Above is a cutaway view of a new sealless centrifugal pump, which also has a magnetic drive, introduced last month by the Chem Pump Corp., a subsidiary of the Milton Roy Co., Philadelphia. The stuffing box and mechanical seals are eliminated by having the rotor isolated from the motor windings by a stainless steel sleeve. The fluid being pumped circulates freely around the rotor, which is directly connected to the pump impeller, and acts as a lubricant. For use on corrosive liquids.

## SOLDIER PLACEMENT SERVICE



Pfc. Eric Kjellmark of Scarsdale, N. Y., one of the soldiers who works on the Scientific and Professional Placement Service at the Army Chemical Center, Maryland, talks to another soldier about a possible future civilian career with one of the many firms and government agencies that use this soldier-operated service. About 180 professional scientists scheduled for release between now and the end of the year, have used this placement opportunity. The Service, which is actually a Committee of the Enlisted Specialists Chemical Engineering Club, invites companies to interview those men soon to be free to accept a civilian job.

## BIOLOGICAL RESEARCH UNIT FOR MONSANTO

Establishment of an agricultural and biological research installation at Creve Coeur, Mo., has been announced by the organic chemicals division of Monsanto Chemical Co.

The facilities, to be known as the Creve Coeur Laboratories, are in addition to the division's 257-acre Hazelwood Farms established earlier this year to field-test agricultural chemicals. Operations on Hazelwood Farms will be handled by personnel of the Creve Coeur Laboratories.

Initially, the staff at Creve Coeur laboratories will consist of three research groups under the direction of L. E. Weeks, P. P. Wallace and O. DeGarmo. The groups will engage in research on soil conditioner applications; herbicides, insecticides and fungicides; and mycology, bacteriology and industrial preservation, respectively.

In addition to the laboratories proper, the installation includes 10,000 sq.ft. of greenhouses for screening and experimental work.

(More News on page 32)

# How Much Does Pre-coating Cost You?

Do you have to use costly fibrous material to get a pre-coat surface that will hold diatomaceous earth or other filter aids you may be using? The high cost of asbestos fibers used day after day, to build up a base for pre-coating, far exceeds the cost of filter cloths.

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have a lower pre-coat cost than any other type of filter. You may be surprised to find how much time and filter aid you can save in pre-coating horizontal filter plates.

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## CHEMICAL SAFETY CONGRESS IN CHICAGO

Safety engineers from the chemical industries will hold a special meeting on chemical plant safety during the 40th National Safety Congress and Exposition in Chicago, Oct. 20-24.

The high point of the chemical sessions will be a symposium Tuesday afternoon, Oct. 21, on safety in chemical plant maintenance. Speakers, one for each department concerned with maintenance work, will cover the special hazards of keeping a plant in operation.

Harold Wheeler, of the Ethyl Corp., will point up the safety considerations that must be given to work scheduling. "Safety in Emergency Maintenance" will be discussed by D. W. Gibson, director of safety and plant protection, Columbia chemical division, Pittsburgh Plate Glass Co. Earl R. Wallace, safety engineer, Eastman Kodak Co., will tell of the special fire hazards present during maintenance work.

The opening session on Monday afternoon, Oct. 20, will hear a symposium on "Pilot Plant and Laboratory Safety," moderated by Howard H. Fawcett, safety supervisor of General Electric's research laboratory.

The Wednesday afternoon, Oct. 22, question and answer period—Safety Clinic for Chemical Industries—will give emphasis to the particular problem of small chemical plants. At this same session E. J. Meyers, of the safety and fire protection division, Du Pont Co., will speak on the "Electrical Hazards in Chemical Plants."

There will be two sessions exclusively devoted to the special hazards involved in making chemical plant food. This fertilizer program will include topics such as fire prevention. A highlight of these sessions will be a demonstration of multiple shot blasting at the Chicago plant of the International Minerals and Chemical Co. J. L. Rosenstein, well-known industrial psychologist, will speak on the human side of the safety problem.

## HAGAN CORP.

### BUYS FOUNDRY

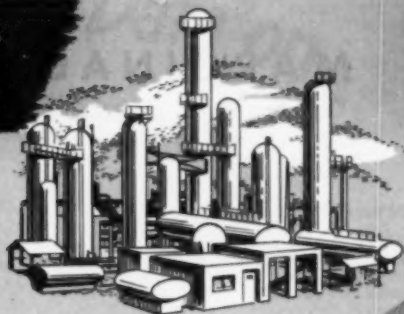
Hagan Corp., combustion and chemical engineering firm, has purchased American Cast Products, Inc., Orrville, Ohio, Hagan president D. J. Erikson announced last month.

The foundry will continue to make grey iron castings under the same manufacturing and sales policies, Mr. Erikson explained. Hagan Corp. needs castings for flow meters and other products and the new subsidiary is directly across the street from the automatic control and flow meter plants of Hagan Corp. in Orrville.

(More News on page 48)

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# MARGINAL NOTES

News of Books of Interest to Chemical Engineers

## Not Just On the Surface

**The Physical Chemistry of Surface Films.** William Draper Harkins. Reinhold Publishing Co., New York (1952). xvi + 413 pp. \$10.00.

Reviewed by Jerome Alexander, Chem. Consultant, New York.

THIS valuable book makes readily available the important work of its versatile author in fields which, as Prof. P. Debye states in the Foreword, "make us understand the molecular structure of surfaces and surface films as the foundation on which colloid chemistry must be erected. The addition of a chapter on lyophobic colloids and their electric double layer, contributed by E. J. W. Verwey, shows how well aware Harkins is of this connection. Personally, I like to consider Harkins' work as a highly important pioneering step on a trail which I trust others will follow, until ultimately we reach a real understanding of catalytic action."

The chapters, which have many sub-headings, are: I. The Nature and Energetics of Surfaces (pp. 93); II. Films on Liquids (pp. 104); III. Films on Solids (pp. 98); IV. Properties of Soap Solutions (pp. 33); V. Mechanism of Emulsion Polymerization (pp. 22); VI. The Role of the Electric Double Layer in the Behavior of Lyophobic Colloids (by E. J. W. Verwey (pp. 19)).

The Index is preceded by sixteen pages listing the 270 papers on a great variety of important topics written by Harkins alone or with students, many of whom have become well-known scientists. About one third of these papers were prepared after his formal academic retirement in 1939 with the title of Andrew MacLeish Distinguished Professor Emeritus, University of Chicago. An eight-page "Introduction" by T. F. Young epitomizes some of Harkins' various outstanding contributions. Thus in 1915, in five papers with E. D. Wilson, there was included "a speculation that the conversion of hydrogen to helium might be a possible source of energy for the sun. Those calculations seem to be the first of the kind ever made." With D. M. Gans and H. W. Newson, he "detected the formation of  $\gamma\text{N}^{10}$ , which may be regarded as the first radioactive element produced arti-

cially." Other work dealt with isotopes, the stability and constitution of atomic nuclei and their relative abundance in nature. He independently advanced the theory of the orientation of molecules in surfaces, as did Sir William B. Hardy and Dr. Irving Langmuir. (Henri Devaux had produced experimental evidence of this as early as 1903, by allowing lenses of fatty acids to chill while floating on the surface of water—the top of the lens, cooled in contact with air, shed water; the bottom, did not). He advanced the idea that the impact of an alpha particle on the  $\gamma\text{N}^{14}$  nucleus formed a short-lived intermediate nucleus  $\gamma\text{F}^{18}$ , which broke down into  $\gamma\text{O}^{17}$  and hydrogen. Though both Rutherford and Harkins independently assumed, as early as 1920, that the neutron exists, it was not discovered until 1935 by Sir James Chadwick. In an historical review in *Science* (1946) Harkins indicates the mass of the proton as 130 million tons/cc. "Thus, the whole earth would have a diameter of only 460 meters, or less than a third of a mile (0.286 mile) if its whole mass were present as protons and neutrons packed as they are in the nucleus of an atom. The presence of electrons, however, reduces the density from  $1.2 \times 10^{14}$  g./cc. to that of the earth (5.522 g./cc.) which is 20 million million times smaller."

Harkins also made important contributions to catalysis, lubrication, synthetic rubber and other industrial fields, including emulsions and emulsion polymerization.

**Properties of the Principal Fats, Fatty Oils, Waxes, Fatty Acids and Their Salts.** M. P. Doss. The Texas Co., New York, (1952) 244 pp. 8½ x 11 (horizontal) \$5.00.

THIS book is the result of ten years' search through published and unpublished data and literature. The unique part of the book is the data given on the salts of the fatty acids ranging from aluminum through zirconium. Only aliphatic acids are surveyed but properties of more than 800 of these are tabulated. Approximately 1750 salts are listed. The book concludes with a variety of pertinent conversion tables (i.e., temperature, gravity, viscosity, color) and a detailed subject index.

## Another Reference Must

**Bibliography of Industrial Drying.** 3 vols. W. H. Bickle. Department of Scientific and Industrial Research, Technical Information and Documents Unit, Cunard Buildings, Regent Street, London, S.W.1, Great Britain. (1951) xxxv + 802 pp. \$6.25.

Reviewed by Thomas K. Sherwood, Dean of Eng., M.I.T., Cambridge, Mass.

THIS monumental work is probably the most complete bibliography of any of the unit operations of chemical engineering. More than 4600 abstracts are listed in five sections; general principles; processes and equipment; agriculture; food and industrial materials. Material covered includes not only industrial drying but also related fields such as the physics of moisture movement in solids, evaporation, turbulence, sublimation, hygrometry, moisture determinations, etc. These volumes belong in every chemical engineering reference library.

## After the Manner of Roget

**The Engineers' Illustrated Thesaurus.** Herbert Herkimer. Chemical Publishing Co., Inc., Brooklyn, N. Y. (1952) 572 pp. \$6.00.

THIS is a reference work and an encyclopedia with more than 8000 illustrations, including typical assembly drawings and example of American and foreign designs, of mechanical movements, machine parts and details. The purpose of the book is to emphasize underlying principles and not structural details. The book has two main divisions: Part I on Statics and Part II on Dynamics. In the first part, I-III, there are three classes, namely, fasteners, adjusting devices, and supports and structures. In the second part, classifications IV through XII cover basic mechanical movements; elevators, derricks, cranes, conveyors; transmission of liquids and gases; combustion; prime movers; transportation; industrial processes; electrical appliances, etc.

The author has modeled his classification on that of Roget's Thesaurus of English Words and Phrases in which a word is classified according to the idea it intends to convey. A detailed alphabetical index concludes the work.

(More Marginal Notes on page 36)

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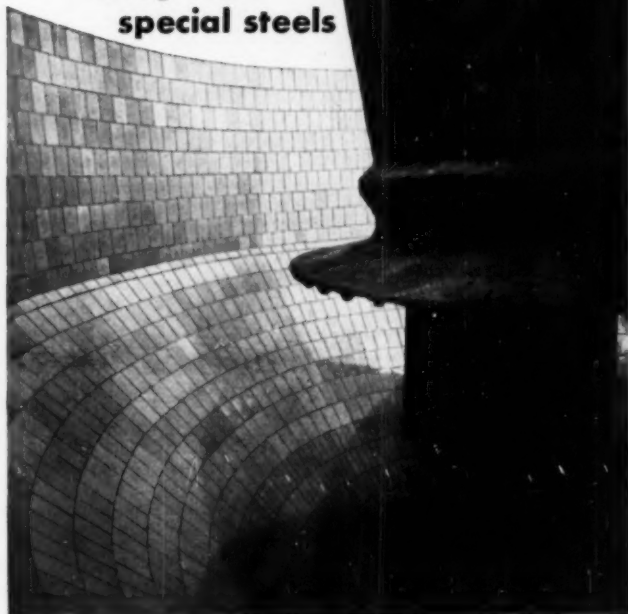
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## MARGINAL NOTES

(Continued from page 34)

### Nomography Made Simple

Nomography and Empirical Equations.  
L. H. Johnson, John Wiley & Sons,  
Inc., New York. (1952) 150 pp. \$3.75.

Reviewed by R. D. Toomey, Dev. and  
Eng. Dept., Titanium Div., National  
Lead Co., South Amboy, N. J.

THIS book describes two techniques which are essential to scientists who must summarize data in a form useful to themselves and others. The construction of nomographs, described in a straightforward manner, is easily understood by anyone familiar with logarithms and elementary geometry. A careful reading of this book will give the average engineer a working knowledge of nomography. As many complex nomographs are included, the book adequately covers the situations which the chemical engineer would normally encounter. The treatment of scale arrangement and relative errors in nomographs is a worth-while section of the book.

The second part on empirical equations begins with a discussion of three methods of curve-fitting including the method of least squares. It is then shown how curves of various types can be transformed into a straight-line relationship so that the best straight line might be fitted to the data. Several curves involving three and four constants are discussed; a knowledge of these curves will satisfy most practical problems.

The author does not delve into the fundamental aspects of either nomography, or empirical equations, nor can the treatments of either subject be considered complete. However, for the scientist with a limited amount of time who would like to become familiar with these subjects and for the person who would like a concise reference book, this text is recommended. In the words of the author he has chosen what is to him the simplest and most direct approach and has not attempted to write a treatise which presents all approaches to these subjects. In this respect the author has been successful.

### Book Received

Heterocyclic Compounds. Vol. 3—Polycyclic Derivatives of Pyrrole; Polycyclic Systems with One Nitrogen Common to Both Rings; Pyridine and Related Compounds. Vol. 4—Quinoline, Isoquinoline, and Their Benzo Derivatives. Both volumes edited by Robert C. Elderfield. John Wiley & Sons, Inc., New York. (1952). Vol. 3, 442 pp., \$12.00. Vol. 4, 674 pp., \$17.00.

(More Marginal Notes on page 38)

# Accidental Thermal Shock?

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## MARGINAL NOTES

(Continued from page 36)

### Operation Cinderella and the Duke

The Science of Flames and Furnaces. M. W. Thring. John Wiley & Sons, New York (1952). 416 pp. \$6.50.

Reviewed by E. L. Piret, Prof. Chem. Eng. University of Minnesota, Minneapolis, Minn.

OUTLINED in this book are the elementary notions of engineering thermodynamics, combustion kinetics, heat transfer and fluid flow which are most helpful to the design of industrial furnaces and to the analysis of their operation. The more scientific aspects of the often complex phenomena of furnace performance are sufficiently introduced (with references) to indicate what and where attempts have been made to study these either in an academic or in an industrial manner.

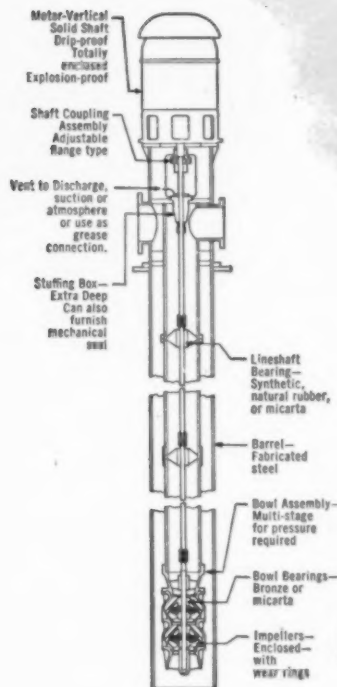
The author refers to the industrial furnace as having the status of Cinderella before the arrival of the Fairy Godmother and hopes that, by giving a glimpse of the possibilities of new and evolving techniques and studies, he can incite others to work towards the transformation of the design methods from the crude and the empirical to the precise and the scientific. One therefore finds in this book brief discussions of topics which are also currently in vogue among some research groups here. These include eddy diffusion, mixing and mixing lengths, electric analogs and statistical analyses of experiments, flame velocities, and combustion theory, tracer techniques and, of course, dimensional similarity.

Many of the quick and ready answers to furnace design problems will not be found in this volume which is, in fact, too broad in its coverage to be thorough in its parts. It is, however, clearly of more basic character than most other furnace design books on the market, and it will, as indicated by the author's objective, encourage the engineer and the research man to seek more rational, more scientific approaches to his problems than those used in the past. It also blends the evidently extensive industrial experience and appreciation of the author with a clear understanding of the manner and advantages of using the results of fundamental research for engineering design and progress. This marriage of science and practice on the British Isles, as forcefully brought out a year ago by the Duke of Edinburgh in a much-publicized address, is apparently not always easy to arrange. This book will help in its field to solve that problem.

(More Marginal Notes on page 52)



**NOTES FROM  
THE PUMP  
ENGINEER'S  
HANDBOOK**



This unit is a vertical turbine type pump designed to handle volatile liquids and liquids near the boiling point. Both suction and discharge are above grade and the pump bowls are enclosed in a steel barrel. This pump offers many advantages where there is a limited NPSH... Bowls are easily set low enough for proper submergence... Expensive dry sumps are eliminated... Nothing to lubricate except driver bearing... Efficiency is comparable with horizontal centrifugals at low heads and is often greater at high heads.

## SHAFT WEAR CAN'T HAPPEN to a Johnston Water-Lubricated Pump!

Here's another **QUALITY** feature that makes Johnston Water-Lubricated Turbine Pumps a good investment. The renewable stainless steel sleeves which shroud the line-shaft at all points of bearing contact make it impossible for sand or other abrasives to damage the shaft. Sure, the sleeve and bearings wear on a pump... but think of the savings on parts and labor alone when you simply replace a sleeve instead of a complete section of shafting. What's more, you don't need a lot of special tools to do the job! Do it at the pump site... just unscrew the old sleeve and thread on the new!!!



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Trained hydraulic engineers are available at your nearest Johnston Dealer or at the Johnston factory to furnish detailed information, proposals and anything else necessary to meet your particular pumping equipment needs.

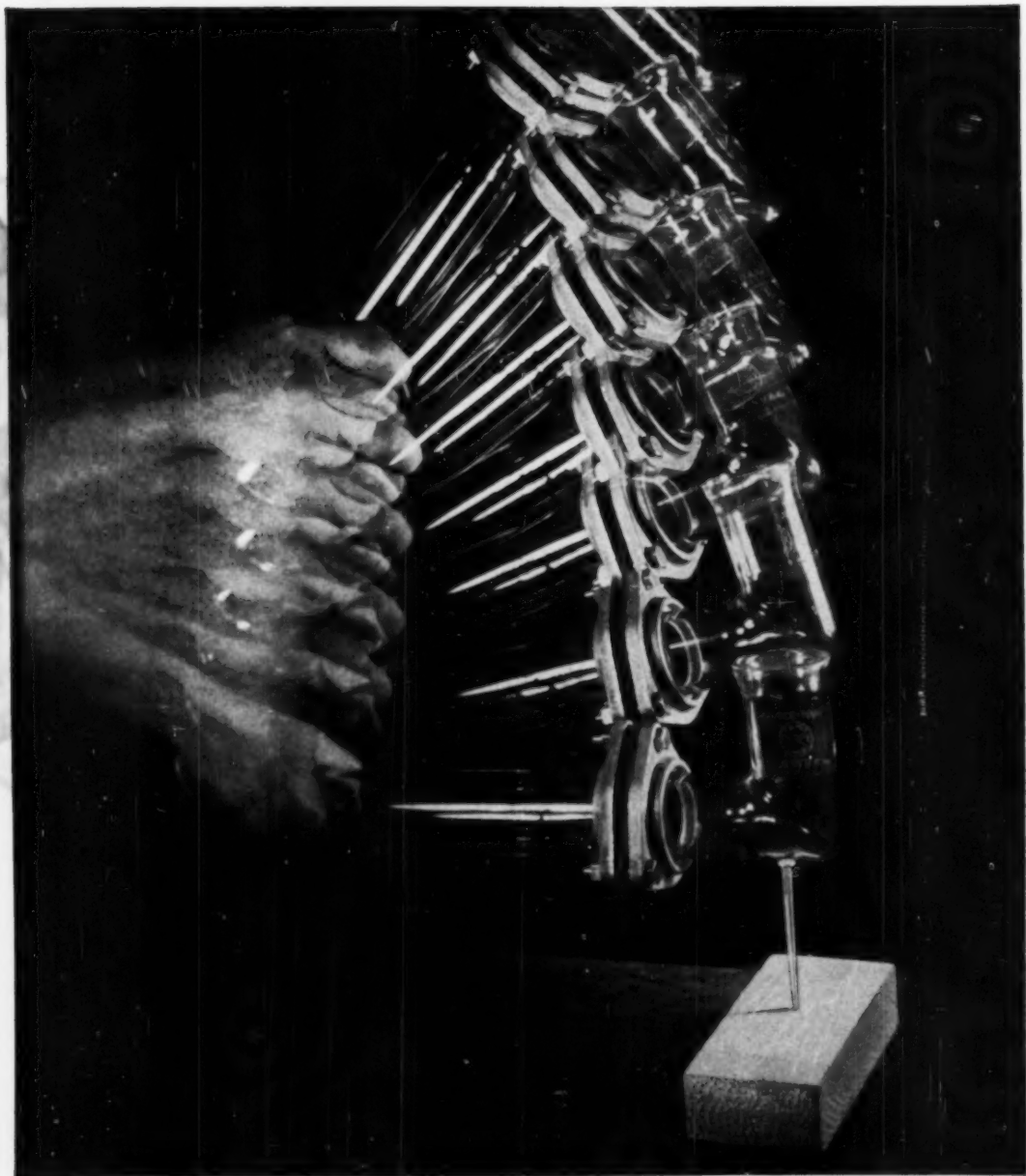
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Its resistance to thermal shock is such that you can use PYREX pipe at temperatures up to 450°F. and shock it 200°F. under full recommended operating pressure. You can even turn live steam into cold outdoor lines!

Mechanical damage is no problem either. First, because plant men respect glass... and this is based on 25 years experience. Second, because PYREX pipe can take a beating. Ends and fittings (except U-bends) are tempered to double their strength.

The corrosion resistance of PYREX pipe is its most outstanding property. It will safely and economically handle, hot or cold, mild alkali solutions and all acids except hydrofluoric.

But long service life with a minimum of replacement costs is only one of the reasons why more chemical plants are switching to PYREX pipe. They also like its transparency which permits them to check for cleanliness and to visually inspect the flow. They know trouble can't hide behind glass.

Drug and pharmaceutical manufacturers like PYREX pipe because it's non-contaminating... protects sensitive products. They also like its hard, smooth, nonretentive surface which permits easy cleaning and assures the cleanest surface known.

And ease and economy of installation and plumbing appeals to everyone because it cuts initial and maintenance costs and provides flexibility.

PYREX pipe is readily available in the following sizes—1", 1½", 2", 3", 4", and 6" inside diameters. A complete line of fittings including elbows, tees, crosses, reducers, laterals, return bends and caps may be had. Glass plug valves are available in 1" and 1½" sizes. There are a wide variety of gaskets now in stock to resist virtually every chemical known.

These PYREX brand glass pipe distributors stock the complete line:

ALBANY 3, NEW YORK  
A. J. Eckert Company

ATLANTA, GEORGIA  
Southern Scientific Co.

BELMONT, CALIFORNIA  
Glass Engineering Laboratories

CAMBRIDGE 39, MASS.  
Macalaster Bicknell Company

CHICAGO 44, ILLINOIS  
Fred S. Hickey, Inc.

FRESNO 17, CALIFORNIA  
Valley Fdy. & Mach. Works

HATBORO, PENNSYLVANIA  
Sartwell Glass Company

ROCHESTER 3, NEW YORK  
Will Corporation

HOUSTON 7, TEXAS  
W. H. Curtin Company

PITTSBURGH, PA.  
Fisher Scientific Company

MONTREAL 3, QUEBEC, CAN.  
Fisher Scientific Company, Ltd.

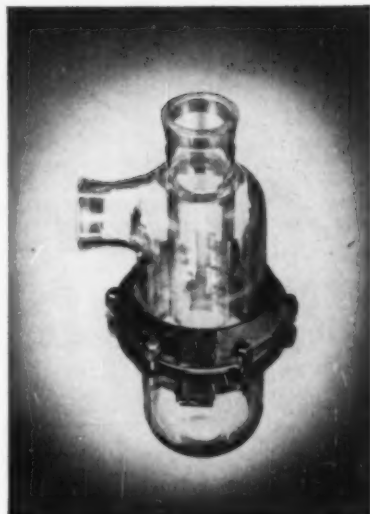
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Scientific Supplies

ST. LOUIS 2, MISSOURI  
Stemmerich Supply Inc.

LODI, NEW JERSEY  
Mooney Bros. Corp.

BUFFALO, NEW YORK  
Buffalo Apparatus Corp.

**PYREX brand "DOUBLE-TOUGH" GLASS PIPE for Drainage Lines.** Where acids and other corrosives are being handled, you'll be sure of substantial savings by installing PYREX pipe drainage lines. One user reports that PYREX pipe paid for itself in his plant in less than nine months in saved replacement costs. Complete fittings are available. Adapter flanges make it a simple matter to join PYREX pipe lines to other types.



**PYREX brand Glass Sink Traps.** This trap is nonsiphoning and permits easy cleaning. There's no plug to unscrew and the bulk of the water remains in the cap. Transparency permits rapid inspection. To assemble, simply use ordinary wrench to tighten.

## CORNING GLASS WORKS

Dept. EP-9, Corning, N. Y.

Please send me the printed information checked below:

- ☐ "PYREX brand Glass Pipe in the Process Industries" (EA-1)
- ☐ "PYREX brand "Double-Tough" Glass Pipe and Fittings" (EA-3)
- ☐ "Plant Equipment Glassware for Process Industries" (ES-1)
- ☐ "Installation Manual" for PYREX brand "Double-Tough" Glass Pipe (PE-3)
- ☐ "PYREX Cascade Coolers" (PE-8)

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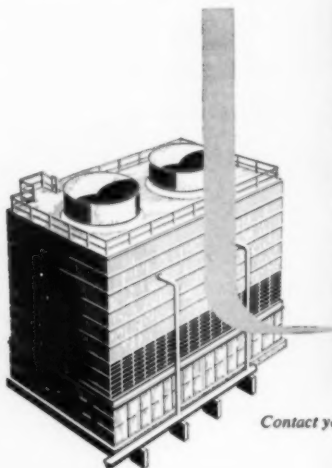


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# ONLY FLUOR

*induced draft counterflow  
cooling towers  
provide these  
6 exclusive features...*



## *Spiral Bevel Gear Speed Reducers*

Only Fluor-Western speed reducers incorporate curved tooth spiral bevel gears as standard design. This proven principle provides quieter, smoother, more efficient operation under the rugged conditions of cooling tower service. Other special design features include: oil-bath lubrication; dry air breather; chrome-plated shaft at oil seals; and, low-speed fan shaft mounted on special steep angle thrust and radial bearings to take combined gear thrust, fan thrust, and weight of fan assembly.



## *Unique Fan Blade Design*

The Fluor Type HC Stainless Steel Fan blades, furnished as standard on every Fluor Counterflow Cooling Tower, are a joint development of The Fluor Corporation and Solar Aircraft Company. Designed specifically for induced draft cooling tower service, their unique air foil handles maximum air volumes at minimum tip speeds and horsepower requirements. Design *plus* mechanical arrangement eliminates recirculation of air and resulting power-consuming turbulence.



## *Internal Gusset Plate Construction*

Fluor Counterflow Cooling Towers alone make full use of tensile as well as compressive strength of structural members! Their internal gusset plate design duplicates that used in wooden bridge construction. These simple, yet extremely strong joint connectors mean longer tower life, lower total tower weight, fewer and simpler castings, greater ease of erection, and minimum spoilage should the structure be dismantled, moved and re-erected.



## *Patented Vibration Cut-Out Switch*

The Vibration Cut-Out Switch developed and patented by Fluor in 1944 protects tower structure and mechanical equipment by stopping the motor should excessive vibration suddenly occur. In addition to its value as an emergency safety device, the switch can be utilized by the operator as a positive "on-off" switch during routine inspection of tower structure and mechanical equipment. The motor cannot be started accidentally once the switch is placed in the "off" position.



## *Sloping-Bar Grid Decking*

Exclusive Fluor-designed sloping-bar grid decks are of rough-finished 1" select redwood machine-nailed to 1" x 2" cleats—strong enough for use as scaffolding during erection, rugged enough to withstand the erosion of falling water. This means low maintenance and replacement cost. The sloping-bar design and arrangement of each deck cross member combines the advantages of maximum deck surface with minimum air pressure drop through tower.



## *Complete Prefabrication of Structure*

Only Fluor Counterflow Cooling Towers are completely prefabricated. This offers many advantages to the operator. Tower parts are "packaged" for rapid delivery, marked for orderly erection. Erection is faster, easier, at lower cost. All cutting, drilling and nailing is completed at the factory. Prefabrication means standardization—low-cost replacement of standard parts that may become damaged over the years. It means uniformity in both performance and appearance.

Contact your nearest Fluor representative for detailed information. You Can Be Sure With Fluor

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Represented in the Sterling areas by:  
Head Wrightson Processes Ltd., Teesdale House, Baltic Street, London, E.C.3, England



# DATA SERVICE

## EQUIPMENT

**1 • HEATING ELEMENTS.** Electrofilm Corp. New flexible heating elements in tape form. For cylindrical heating applications up to 300° F. Tape holding heating elements is electrically resistant plastic which is wound around unit to be heated.

**2 • PLASTIC PIPE AND FITTINGS.** Kraloy Plastic Pipe Co. with six different types of plastic pipe and fittings for various chemical purposes. Pipe from 1 to 5 in. I.D. Chemical resistance chart in bulletin.

**3 • TRANSPARENT FLANGE SHIELDS.** Transparent polyethylene flange shields to fit over pipe flanges. For visual detection of leaks. Corrosion resistant; in nine standard sizes for pipes 3/4 in. diam. to 6 in. Packing Engineering Corp.

**4 • MASK SHIELD.** A plastic mask and cotton gauze filter for protection of workers against light dusts and flying chips. Low-cost unit from General Scientific Equipment Co.

**5 • INSULATING TAPE.** From Bishop Mfg. Corp. Korkwrap, a new insulating tape for air-conditioning units, refrigerating units, water chillers, etc. Prevents pipe sweating. Self-bonding.

**6 • SCREW PUMP.** An internal gear-and-bearing-type screw pump for positive displacement of viscous materials. Capacities from 100 to 700 gal./min.; discharge pressures from 500 lb./sq.in. to 1000 lb./sq.in. For connection to high-speed motors. Interchangeable rotor screws. Sier-Bath Gear & Pump Co., Inc.

**7 • GAS MASK VALVE.** For prevention of frozen gas mask valves Acme Protection Equipment Co. with a new Protect-A-Valve. Also prevents curled valves due to rubber solvents.

**8 • COOLED MOTORS.** Totally enclosed fan-cooled geared motors from Sterling Electric Motors, Inc.

Units have double reduction gears for heavy duty work; 5 to 25 hp. and speeds up to 155 rev./min.

**9 • PULP PRESS.** Jackson & Church Co. continuous pulp press for separation of liquids from pulps and slurries. For use in paper mills, beet-sugar refineries, canneries, and other plants with a problem of separating liquids from pulp.

**10 • PRESSURE-LEAF FILTER.** For quick discharge of large quantities of semi-dry cakes, a new Niagara Filter Corp. Style H pressure-leaf filter. Retractable-carriage style adapted for filtration where a high percentage of solids must be removed.

**11 • SURFACE PYROMETER.** A new surface pyrometer from The Pyrometer Instrument Co., Inc. Adaptable to fourteen different thermocouples and extension arms. Quick-change connector; thermocouples interchangeable without adjustment. Temperature in five different ranges on a direct-reading dial.

**12 • ARMORED FLOW METER.** A new line of armored flowmeters for high-pressure fluid flow measurement and control from Fischer & Porter Co. For use where high temperature, high pressure, liquid hammer, or hazardous fluids make normal operation hazardous.

**14 • FLEXIBLE MOTOR CONTROL.** A lightweight variable-speed motor with a mechanical remote control new with U. S. Electrical Motors, Inc. Control features a hand wheel with indicator dial, and a 5-ft. flexible motor control. Longer control cables available. Range 1/4 through 1/2 hp. range with speed ratios up to 10 to 1.

**15 • DYNEL WORK CLOTHES.** A line of work clothes from Dynel by American Allsafe Co., Inc. For chemical plants, petroleum refineries, etc., processing corrosive materials and where the life of conventional clothing is short.

**16 • INSTRUMENT ISOLATOR.** Trans-Sonics, Inc., has a new isolator for separating highly corrosive fluids or gases from liquid-filled pressure gages and other instrumentation systems. Models available for pressures up to 3000 lb./sq.in. Device utilizes a Kel-F diaphragm to stop corrosive media and to transmit the line pressures.

**17 • VACUUM PROCESSING SYSTEMS.** A revised edition of a catalog of F. J. Stokes Machine Co. on vacuum processing systems. Much new apparatus described, including rotary and rotating vacuum-dryers, shelf-dryers, freeze-drying equipment, impregnators, etc.

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**18 • MONOTUBE DRYER.** For recovering by-products and solvents, as well as drying and cooling, are the triple functions of the new Link-Belt Co. Monotube dryer. Operates on conduction principle of heat transfer, steam, hot liquid or coolant circulating through a hollow shaft of a paddle conveyor. Dusting eliminated. For a wide variety of chemicals, pharmaceuticals, etc.

**19 • EYE WASH FOUNTAIN.** As a safety fountain in industrial accidents for spraying eyes, ears, nose, and mouth, a new fountain by Logan Emergency Showers, Inc. Eliminates back syphonage, uses new principles of spraying, and is actuated by a bating valve.

**20 • ELECTRO-PHORESIS.** A new Beckman Instruments, Inc., electrophoresis-convection apparatus. For separating a mixture of proteins into distinct components. Details describing operation of the instrument available.

**21 • STYROFOAM.** For low-temperature installations Dow Chemical Co. publication on Styrofoam low-temperature plastic insulation. Bulletin shows how low thermal conductivity of 0.23 B.t.u./ (hr.) (sq.ft.) (°F./in.) is adapted in various applications. Principles of proper installation, wall construction, how to apply adhesives to the material, etc.

**22 • SEAL-LESS CENTRIFUGAL.** A new centrifugal pump without seal or stuffing boxes. Uses magnetic drive with the rotor isolated from the motor winding. Fluid acts as lubricant. Milton Roy Co. development. For use in pumping corrosive materials.

**23 • AIR AND GAS DIFFUSER.** A new piece of equipment for fine diffusion of air or gas into a liquid in sewage and industrial waste treatment. Inflico, Inc. Diffuser is flexible and collapsible, of acid-proof fabric, easily cleaned by operation of a three-way valve which shuts off air or gas pressure, inverting the element into receptacle. Bulletin available.

**24 • PROCESS MACHINERY.** Hardinge Co., Inc., has a new 8-page bulletin describing complete line of process machinery for mining, chemical, stone, ceramic, mineral, paper, etc., industries. Includes oil-water separators, heavy-media separators, flocculating equipment, etc.

toxicity, stability, and a bibliography. Nitroparaffins are mild oxidizing agents and can be used as solvents for aluminum chloride for alkylation reactions, etc.

**26 • RUBBER LININGS.** A listing from La Favorite Rubber Mfg. Co. of acids, alkalis, and other corrosive materials for which satisfactory corrosive resistant linings have been developed. Gives name of compound, concentration, temperature range, and designation of the corrosion resistant lining.

**27 • GLYCERINE FACTS.** A news letter type of bulletin on the use of glycerine in industry. Information on glycerine supply, its use in textile sizes; in a calamine formula; alkyl resins, plus a half-page of glycerine oddities. Glycerine Information Service.

**28 • DIBUTYL PHTHALATE.** From Witco Chemical Co. a technical service report describing the uses and properties of dibutyl phthalate. Used as a plasticizer for nitrocellulose lacquers. Data sheet gives physical properties, analysis.

**29 • INSECTICIDE INFORMATION.** From McLaughlin, Gormley, King Co. a packet of information on insecticides on the use of allethrin, fly sprays around food and cattle, the use of booster concentrates for roach sprays, an insecticide synergist, pyrethrin products, and allethrin concentrates. Technical data, concentrations, formulas, etc., in this roundup of reprints, data sheets, etc.

**30 • HYDROGEN PEROXIDE.** For food processors, a one-page technical bulletin from Buffalo Electro-Chemical Co. on the use of hydrogen peroxide. Gives specifications, properties, shipping information, etc.

**31 • PENTAERYTHRITOL.** Bulletin on

## CHEMICALS

**25 • NITROPARAFFINS.** Technical data sheet from Commercial Solvents Corp. on nitroparaffins, i.e., n-methane, nitroethane, 1-nitropropane and 2-nitropropane. Gives flash points,

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technical grade of pentaerythritol used in rosin and tall oil esters, synthetic drying oils. Gives physical properties, specifications. Commercial Solvents Corp.

**32 • TRIBUTYL PHOSPHATE.** Bulletin on technical grade of tributyl phosphate used in synthetic latex paint, paper manufacture, antifoam. Gives physical properties, specifications, etc. Commercial Solvents Corp.

**33 • CHLORINE TRIFLUORIDE.** Pennsylvania Salt Mfg. Co. announces commercial production of chlorine trifluoride. Dense liquid contains 61.7% fluorine, comparable to fluorine in reactivity and other characteristics but can be conveniently handled, stored and shipped. Liquefied at pressures of 10-20 lb./sq.in. gage. For use in the manufacture of fluorine, in chlorofluorine chemicals, as an oxidizing agent in rocket fuels, production of high temperatures for cutting metals and siliceous materials.

**34 • VINYL PLASTICIZER.** A technical service report on Di-(2-Ethylhexyl) Adipate as a primary plasticizer for vinyl resins. From Witco Chemical Co. Physical properties, analysis, use, advantages, etc.

**35 • METALLIC STEARATES.** A publication on revised specifications of metallic stearates. Includes controls on purity and uniformity, plus a listing of the entire metallic stearate line used in petroleum, rubber, graphite, etc., fields. American Cyanamid Co.

**36 • PLASTICIZERS.** An illustrated booklet from Pittsburgh Coke & Chemical Co. on plasticizers. Covers dibutyl phthalate, Diiso-Octyl phthalate, adipates, sebacates, tricresyl phosphate, furfuryl oleates, etc.

**37 • PLASTICIZERS.** A Dow Chemical Co. technical bulletin on plasticizers.

Gives technical specifications, typical properties, uses, solubility, etc. Covers aryl phosphates, phenyl ethers, and a polymolecular resin plasticizer.

**38 • CARBON BLACK.** J. M. Huber Corp. publication on carbon blacks and electrical conductance. Illustrates testing procedures, and effects of carbon black loading and dispersion on electrical conductance.

**39 • LATEX FOR PAINT.** Extensive technical data bulletin from Dow Chemical Co. offers suggestions on methods of making latex paint. Recommends types of plastics to be used with the latex, gives properties, processing, etc.

**40 • N-PROPYL ACETATE.** Tank car quantities now being made by the chemical division of Celanese Corp. of America. First in a series of esters. Formulations and uses for the product available.

**41 • NEOLYN RESINS.** Hercules Powder Co. technical bulletin containing applications, starting formulations, on the use of neolyn resins in adhesives, plastics, lacquers, and organosols. Neolyn resins are rosin-derived alkyl types with a range of hardness. Data on two new resins.

**42 • 2-ETHYLHEXANOL.** Technical bulletin on bulk quantities of 2-ethylhexanol. Carbide & Carbon Chemicals Co. Used in preparing surface coatings, textiles, insect sprays, disinfectants, as a solvent defoamer, wetting agent, etc. Bulletin lists physical and chemical properties, shipping data, etc.

**43 • ORTHO-ETHYLNITROBENZENE.** Monsanto Chemical Co. technical bulletin on (1-ethyl-2-nitrobenzene). Data on properties, reactions, uses, structure, bibliography, and shipping information.

**44 • N-BUTYL ALCOHOL.** Chemical, physical, physiological properties, solubility, shipping data, applications of n-butyl alcohol. Carbide & Carbon Chemicals Co. For synthetic resin, plastic, pharmaceutical, etc., industries.

**45 • STYRENE MONOMER.** Monsanto Chemical Co. publication on styrene monomer which gives types of available solutions and dispersions. For water-based paints, paper coatings, adhesives, etc. Well-illustrated, large bibliography of starting points for new plastic developments, specifications, etc.

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## BULLETINS

**50 • PORCELAIN VALVE.** Porcelain Y valve with teflon cap and pin fitting into a precision ground seat. Stop nut on stem indicates valve position. Sizes form  $\frac{1}{2}$  to 6 in., pressures up to 110 lb./sq.in. General Ceramics & Steatite Corp.

**51 • BAG HANDLER.** A machine for flattening, elevating, and loading bags, made by the Power-Curve Conveyor Co. Illustrated, operation described, advantages, etc.

**52 • NI-RESIST.** From International Nickel Co. a publication on engineering properties and applications of Ni-Resist. Covers all technical information of value to chemical engineers, including corrosion properties and the advantages of particular alloy. Extensive table of chemical corrosion tests giving duration of test, temperature, aeration, velocity, etc.

**53 • 53A • COLLECTOR SYSTEMS.** Claude B. Schneible Co. publications. 53 on a multiwash collector system for odor, fume and dust control in the paint, varnish and printing-ink industries. 53A on Schneible multiwash dust-collector systems and dewatering tanks and pumps. Latter bulletin is of general type explaining principles, installations, equipment, etc.

**54 • VALVE CAPACITY CALCULATOR.** A free circular slide rule from Kieley & Mueller, Inc., for rapid determination of flow through a valve, pressure drop, or valve size. Can determine the above for liquids, steam, or dry gas for valve sizes  $\frac{1}{4}$  in. to 20 in., pressure drops from  $\frac{1}{10}$  to

10,000 lb./sq.in., and rate of flow in a range of 0.1 to 10,000. Instruction booklet with slide rule gives examples of use.

**55 • NEPHO-COLORIMETER.** For haze analysis of small fractions of impurities in solutions, Wilkens-Anderson Co. combined nepho-colorimeter. Detects sulfur to 16 p.p.m., calcium in water 0.5 p.p.m. Also used in filtration control growth of microorganisms, control of color in beverages, etc.

**56 • TURBOPUMP.** For continuous boiler feed service, a steam turbopump from Pacific Pumps, Inc. Single-stage-diffuser type.

**57 • HIGH-PRESSURE REGULATOR.** For control of air, gas, or liquids at high pressures and low volume, Grove Regulator Co. in production with a new unit. Seats are stainless steel, valves are molded nylon rod. Various ranges and pressures.

**58 • ANALYTICAL REAGENTS.** Price catalog of analytical reagents and other chemicals from Mallinckrodt Chemical Works. Gives price for various size containers, and in many cases the maximum limit of impurities.

**59 • INSULATION.** A folder which tells the combined insulating values of Mono-Block insulation and Powerhouse insulating cement. Mono-Block is a black mineral wool processed into a rigid block, the cement, a dry mixture of black mineral wool and binder. Data on insulating properties. Baldwin-Hill Co.

**60 • MIXERS.** Premier Mill Corp. on

the use of Premier Dispersator for mixing, agitating, contacting, washing, dissolving, wetting, etc. Photographs show how the Dispersator works. Instead of a propeller or paddle on the end of the rotating shaft a special slotted, hollow cone does the mixing and dispersing.

**61 • PROCESS EQUIPMENT.** From Schmieg Industries, Inc., a catalog on dust and fume control equipment, spray booths, mechanical washers, industrial ovens, and other equipment and accessories. Illustrations of installations, sectional drawings.

**62 • PLANNING VENTILATING SYSTEMS.** From ILG Electric Ventilating Co. an extensive bulletin on proper planning of ventilating systems. Shows the proper size fan to use, how to use ducts, faults to avoid, various types of installation, sound-proofing, etc. For the engineer faced with ventilating problems this booklet gives many hints.

**63 • CATALYTIC COMBUSTION.** Catalytic Combustion Corp. explanatory folder on how catalysts will help to reduce odors from plant. Shows principles of operation and combustion of gas, the method of catalyst operation. Applications are shown on how odors and fumes are turned into odorless, colorless, oxidized materials. For use in asphalt, foundry, fat rendering, petroleum refining, pharmaceutical manufacturing, organic chemical plants, etc.

**64 • POLYVINYL EQUIPMENT.** American Agile Corp. on equipment made from unplasticized polyvinyl chloride. Advantage is corrosion resistance of a special, unplasticized polyvinyl free from copolymers. Physical properties, views of equipment such as exhaust hoods, pipe ducts, solution tanks, heat exchanger coils.

**65 • PROCESS EQUIPMENT.** Allis-Chalmers Mfg. Co. catalog of equipment made for the process industries. Indexed, covers pumps, blowers, compressors, crushers, mills, screens, dryers, scrubbers, metal detectors, drives, electric and electronic controls, etc.

**66 • INDUSTRIAL MAGNIFIERS.** A 24-page guide on this subject from Bausch & Lomb Optical Co. for use in the laboratory, plant or office, to improve quality, cut costs and increase production.

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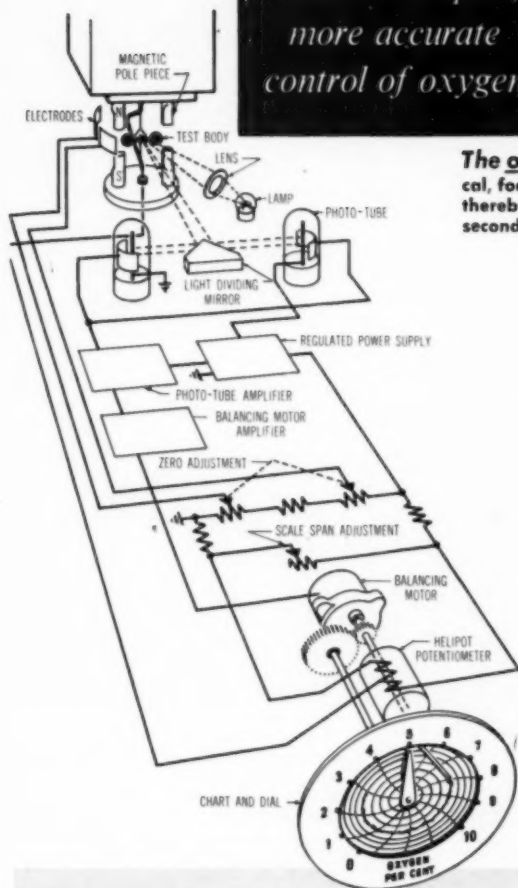
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Now—simpler,  
more accurate  
control of oxygen

## ...in chemical processes...with the Arnold O. Beckman Oxygen Analyzer



**The only oxygen analyzer that employs a direct, physical, fool-proof method for measuring oxygen content in gases, thereby eliminating difficulties encountered in conventional secondary methods of measurement!**

The tremendous advantages of the Arnold O. Beckman Oxygen Analyzer stem from the principle that oxygen is extremely paramagnetic (drawn into a magnetic field), whereas other common gases with few exceptions are diamagnetic (repelled out of a magnetic field). This property of oxygen is so pronounced that oxygen concentrations of only a few parts per million can be detected by the Arnold O. Beckman Oxygen Analyzer simply by measuring the magnetic susceptibility of the gas. This measurement is purely physical, not a chemical analysis, and is accomplished without recourse to filaments, catalysts, chemicals, fuels, etc.

**The principle:** When a test body within the instrument is surrounded by gas, the body is either drawn closer to the region of maximum magnetic flux density, or it is repelled in proportion to the oxygen content of the gas. As indicated at left, the result is recorded directly on any conventional recording potentiometer.

The sensitivity and accuracy of the Arnold O. Beckman Oxygen Analyzer surpasses that of any other method of oxygen determination. Its simplicity eliminates practically all maintenance. No chemicals or replacements are required. There are no platinum filaments, catalysts, cams or mechanical parts to adversely affect its accuracy. No delicate glassware, capillaries, orifices, mixing chambers, float valves, etc., subject to clogging and failure. It is completely automatic in its operation. Variety of ranges is greater than obtained by any other commercial analyzer and multi-range instruments are available. Sampling is simpler. In all respects, the Arnold O. Beckman Oxygen Analyzer is the most convenient, most versatile, most trouble-free and most accurate oxygen recorder yet developed.

Write for Bulletin 105 for general information on all models, or for Bulletin 103A on the recording Model G-2. Arnold O. Beckman engineers welcome the opportunity to help you with your oxygen analysis problems.

**SELECTIVITY** Highly sensitive to oxygen. Effects of gases other than oxygen are negligible.

**MANY RANGES** From a few parts per million to 100%  $O_2$ . Multi-range instruments are available.

**HIGH ACCURACY** Readings are accurate within  $\pm 1\%$  of the full scale for spans of 2%  $O_2$  and greater (e. g. .02%  $O_2$  on 0-2%  $O_2$  range). Narrower spans as accurate as 20ppm. Accuracy is unaffected by ambient temperature variations.

**LINEAR SCALE** Calibration of the Model G-2 is strictly linear and scale is accurate over the entire range.

**SIMPLE SAMPLING** Only a small volume is necessary—50-250 cc. per minute. Accuracy is not affected by variations in flowrate. Samples may be dry or saturated. Nothing is added to the sample, and it may be returned to the process unchanged. Many corrosive or reactive gases can be analyzed.

**COMpletely AUTOMATIC** Sampling and measurement are continuous and automatic. No attendant is necessary.

**RUGGED CONSTRUCTION** The unit is shock mounted to protect it from extreme vibration or shock.

### Features of the Beckman Model G-2

**LOW MAINTENANCE** Because of its simple design, the G-2 requires very little attention. No chemicals, filaments, wicks, etc. to replenish. No orifices, glassware, etc. to clean and replace.

**MANY MODELS** Arnold O. Beckman, Inc. manufactures many types of oxygen analyzers—completely portable, semi-portable, of deflection or null type, and recording instruments. Accessory equipment (alarms, signals, automatic reset control equipment, etc.) are also available.

**Arnold O. Beckman** INC.

Manufacturers of Industrial and Scientific Instruments  
1020 MISSION STREET  
SOUTH PASADENA, CALIFORNIA

# SECRETARY'S REPORT

S. L. TYLER

THE August meeting of the Executive Committee, because of the nature of the agenda, was handled by mail ballot. The Minutes of the previous Executive Committee meeting (July 11) were approved as issued. The Treasurer's report for the month of July was received and approved and the bills for the month were approved for payment.

Those applicants for membership whose names were listed in "C.E.P." in July, 1952, were elected to the grades as indicated.

The following additions were made to the Local Sections Committee: F. P. LaBelle, representing the Atlanta Section, Roland Voorhees, representing the Charleston Section and replacing D. J. Porter and Frank White, representing the New York Section, replacing H. L. Malakoff.

F. Drew Mayfield was added to the Research Committee.

The following were appointed as representatives of the Institute on the E.C.P.D. Committees as indicated:

Guidance Committee—P. D. V. Manning; Education Committee—G. G. Brown; Student Development Committee—J. M. Church; Training Committee—H. G. Donnelly; Recognition Committee—L. C. Kemp; Ethics Committee—T. H. Chilton, and Information Committee—F. J. Van Antwerpen.

Two resignations from membership were received and accepted.

R. A. Morgen, Jr., and Charles A. Brockmiller were placed on the Suspense List because they entered the Armed Forces of the U. S. Paul K. Mulvany has resumed his membership having been discharged from the service.

The dates of March 8, 9, 10, 1954, were approved for a national meeting of the Institute to be held in Washington, D. C.

## DECHEMA MONOGRAPHS

The twenty-three lectures which were delivered at the recent "European Convention of Chemical Engineering," held at Frankfurt am Main in conjunction with the 25th Congrès International de Chimie Industrielle and the Achema X, will shortly appear in a new volume of the DecHEMA Monographs, according to the organization. The volume will have the following main themes:

Basic Chemical Engineering.  
Automatic Measuring and Control Devices in the Laboratory and Works.  
Continuous Chemical Processes.  
The Realization of Extreme Conditions in Chemical Engineering.  
Materials and Corrosion.

Comprising about 500 pages, the publication will sell for \$37.50 per volume.

Orders should be sent to DecHEMA, Deutsche Gesellschaft für chemisches Apparatewesen, Frankfurt am Main 13, Postfach.

## M.C.A. BEGINS

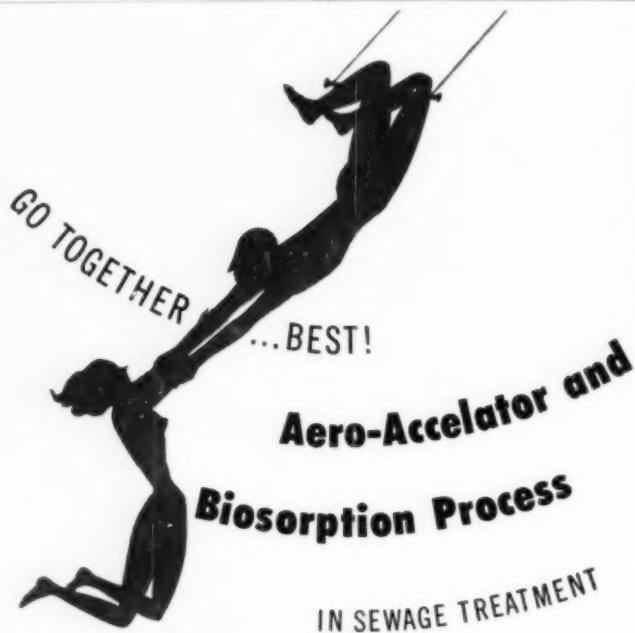
### STUDENT DRIVE

A drive to get more students into the chemical field was asked of the nation's chemical companies by the Manufacturing Chemists' Association last month and as an initial tool in the program, the companies received copies of a manual outlining various student guidance activities.

The chemical industry may more than triple its sales volume by 1975, according to forecasts by M.C.A. board chairman William H. Ward, and the increase in students in chemistry and chemical engineering is far slower than the rate of expansion by the industry.

Object of the drive is to inform high school students, teachers, and parents of the career opportunities for qualified young scientists in industrial chemistry and chemical engineering. The manual details suggestions for doing this by plant tours, classroom talks, etc.

(More News on page 54)



For best results use the team that goes together best...  
Infilco's BIOSORPTION PROCESS and the AERO-ACCELERATOR.

The BIOSORPTION PROCESS has shown phenomenal results in the reduction of B.O.D. and suspended solids. So also are the results in efficiency, low maintenance and appreciable space-savings. The advantages of the AERO-ACCELERATOR as a combined mixer-clarifier have been proved in many diversified installations. Together these two form a winning team.

Ask for bulletins describing Infilco's BIOSORPTION PROCESS and the AERO-ACCELERATOR. See how the combination of these two can pay out handsomely.



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**How  
Celite  
filtration  
assures purity,  
speeds production**

When producers of antibiotics sought a filter aid that would assure removal of all mycelium and other gelatinous impurities in the broth from which wonder drugs are extracted—and speed their "put-through" in the bargain—Celite ended the search.

The effectiveness of Celite can be attributed to these important factors which make it unique among filter aids:

Carefully processed from the purest deposit of diatomaceous silica known, Celite is available in nine standard grades—each designed to trap out suspended impurities of a given size and type. Whenever you reorder, you are assured of the same uniform, accurately graded powder re-

ceived in your initial order. Thus, with Celite, you can count on consistent purity in your filtrates—at highest rate of flow—month after month, year after year.

The manufacture of wonder drugs is just one of the many processes in which consistent purity and faster filtration have been obtained through the use of Celite. Your own filtration problem, regardless of the product involved, can no doubt be solved with the proper grade of Johns-Manville filter aid. To have a Celite Filtration Engineer study your problem and offer recommendations, without cost or obligation, just write Johns-Manville, Box 60, New York 16, N. Y.

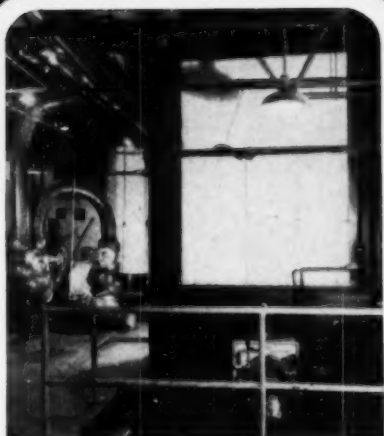
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For highly satisfactory and efficient hot-oil circulating equipment, for clean, quiet, safe transfer of heat to your process equipment, you can't buy a better system than Merrill Process.

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- AUTOMATIC THERMAL OVERLOAD PROTECTION
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- EXTREMELY LONG-LIVED—30 years continuous operation not unusual

Why not drop us a line for further Engineering data, or describe your high temperature problem? We will be glad to make recommendations without obligation on your part:

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## CANDIDATES FOR MEMBERSHIP IN A. I. Ch. E.

The following is a list of candidates for the designated grades of membership in A.I.Ch.E. recommended for election by the Committee on Admissions.

These names are listed in accordance with Article III, Section 7, of the Constitution of A.I.Ch.E.

Objections to the election of any of these candidates from Active Members will receive careful consideration if received before October 15, 1952, at the Office of the Secretary, A.I.Ch.E., 120 East 41st, New York 17.

### APPLICANTS FOR ASSOCIATE MEMBERSHIP

Daniel, Cuthbert, *New York, N. Y.*  
Lamb, Gerald L., *Charleston, W. Va.*  
Mason, David M., *Los Angeles, Calif.*  
Weyermuller, Gordon, *Chicago, Ill.*

### APPLICANTS FOR JUNIOR MEMBERSHIP

Adolphson, Lynn C., *Minneapolis, Minn.*  
Ahles, L. J., *Ripon, Calif.*  
Alpert, Seymour B., *Trenton, N. J.*  
Alston, J. L., Jr., *Oak Ridge, Tenn.*  
Andersen, James A., Jr., *Western Springs, Ill.*  
Anderson, Reg. S., *Pladju, Sumatra, Indonesia*  
Apostolina, Alexander, *Stamford, Conn.*  
Barr, Norbert P., *Oak Park, Ill.*  
Barrett, Donald H., *Sweetwater, Tex.*  
Bartels, Henry J., *Niagara Falls, N. Y.*  
Bean, David C., *Baldwin, N. Y.*  
Bechtold, Charles L., *North Bergen, N. J.*  
Benham, Alvin L., *Lawrence, Kan.*  
Berenholz, Jack, *Bronx, N. Y.*  
Berglund, Wm. K., *Gainesville, Fla.*  
Bigda, Richard J., *Houston, Tex.*  
Bohnslav, Edward, Jr., *Dayton, Ohio*  
Botfeld, Bernard, *Boulder City, Nev.*  
Bowers, John C., *Savannah, Ga.*  
Bright, James O., *St. Louis, Mo.*  
Bright, John A., Jr., *Baltimore, Md.*  
Chapman, Sheldon, *Columbus, Ohio*  
Chmielowiec, Louis J., *Mt. Home Air Force Base, Idaho*  
Conklin, David A., *Hempstead, N. Y.*

Curran, Charles S., *West Point, Pa.*  
Donahue, John Lewis, *Chicago, Ill.*  
Dong, Walter, *Sacramento, Calif.*  
Eumont, Harry W., Jr., *Wilmington, Calif.*  
Fahlgren, Charles E., *Bozeman, Mont.*  
Farran, Richard A., *Grand Rapids, Mich.*  
Flanagan, Andrew J., *Laurelton, N. Y.*  
Forbes, Richard H., *Alexandria, Va.*  
Fortunato, Emil C., *Newark, N. J.*  
Franson, G. Richard, *Hibbing, Minn.*  
Gagliardi, George Nichols, *West Hempstead, N. Y.*  
Gambro, A. John, *New York, N. Y.*  
Geaman, J. Richard, *Birmingham, Mich.*  
Glancy, William G., Jr., *Somerville, N. J.*  
Gordon, Kenneth Fraser, *Berkeley, Calif.*  
Grant, Norbert R., *Detroit, Mich.*  
Graybill, Wilmer B., *Corpus Christi, Tex.*  
Gregory, Wm. P., *Institute, W. Va.*  
Gross, Howard W., *Brooklyn, N. Y.*  
Hall, Wallace G., *Highland Park, Mich.*  
Hamblin, R. J. J., *Pointe-a-Pierre, Trinidad, B. W. I.*  
Heckerroth, Earl T., *Alburton, Mont.*  
Hefner, Robert J., *San Francisco, Calif.*  
Herrington, Arthur C., *Boston, Mass.*  
Heym, George E., *Blacksburg, Va.*  
Hirasawa, Paul S., *Seattle, Wash.*  
Holerman, Elmore, Jr., *Brooklyn, N. Y.*  
Hones, Leonard R., *Charleston, W. Va.*  
Horvat, George John, *Atlantic Highlands, N. J.*  
Howard, Hinton K., *Chattanooga, Tenn.*  
Ivins, Owen D., *Midland, Mich.*  
Justus, Richard F., *St. Louis, Mo.*  
Kaufman, Frederic S., Jr., *Cranford, N. J.*

## CANDIDATES

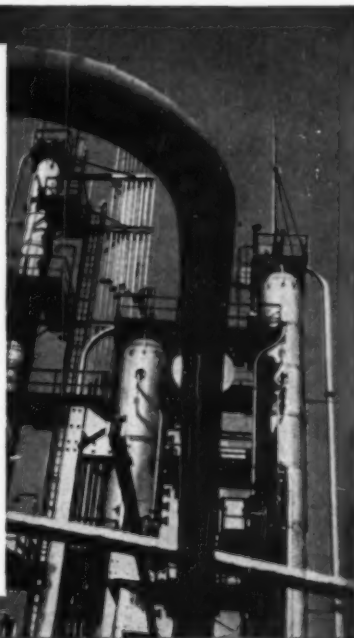
Kellogg, Donald R., *St. Louis, Mo.*  
 Kendall, Robert M., *Pasadena, Calif.*  
 Kinney, Ronald L., *Toledo, Ohio*  
 Kiorpes, Stephen A., *Bartlesville, Okla.*  
 Knudsen, Harold M., *Seattle, Wash.*  
 Kuhlke, William C., *Westfield, N. J.*  
 Leonard, Joseph James, *Hempstead, N. Y.*  
 Malone, Jean F., *Charleston, W. Va.*  
 Marmion, Paul G., *Brooklyn, N. Y.*  
 McCue, Eldon J., *Savannah, Ga.*  
 Meeker, Kenneth Elzo, *Salinas, Calif.*  
 Moore, Harry R., *LeMarque, Tex.*  
 Morgan James P., *Oil City, Pa.*  
 Motte, Eugene I., *Berkeley, Calif.*  
 Mottola, Alexander C., *China Lake, Calif.*  
 Mullins, James A., *Denver, Colo.*  
 Nation, Paul F., *Brighton, Mass.*  
 Ness, Conrad M., *Chisolm, Minn.*  
 Nimick, George G., *Philadelphia, Pa.*  
 Novitsky, Richard Stephen, *Akron, O.*  
 O'Brien, William J., *Pearl River, N. Y.*  
 O'Donnell, Edward, *El Dorado Ark.*  
 Ohnmeiss, Fred C., *Charleston, W. Va.*  
 Olson, Leroy R., Jr., *Midland, Mich.*  
 Palkovic, John J., *Youngstown, Ohio*  
 Park, Russell A., *Philadelphia, Pa.*  
 Pfeffer, Martin, *Brooklyn, N. Y.*  
 Pikaar, Robert J., *Martinez, Calif.*  
 Resnick, Hyman, *Dorchester, Mass.*  
 Roll, Kempton H., *New York, N. Y.*  
 Ruby, William S., *Floral Park, N. Y.*  
 Rummel, M. Frank, *Columbus, Ohio*  
 Russell, Paul F., *San Francisco, Calif.*  
 Sackrisson, Norman B., *Chicago, Ill.*  
 Scheer, Theodore H., *Fallbrook, Calif.*  
 Smith, David M., *Maplewood, N. J.*  
 Sorrenti, G. Roy, *Alhambra, Calif.*  
 Stansfield, Manfred D., *New York, N. Y.*  
 Stephenson, Robert W., *Alameda, Calif.*  
 Stevens, William D., *Topeka, Kan.*  
 Tillquist, George E., *Chicago, Ill.*  
 Toth, Robert C., *Throop, Pa.*  
 Van Der Hoeven, William R., *Beaver, Pa.*  
 Walker, V. A., *Wilmington, Del.*  
 Warren, Edwin C., *Savannah, Ga.*  
 Wersinger, John P., *Hasleton, Pa.*  
 White, A. Fred, Jr., *New York, N. Y.*  
 Wollrab, Warren L., *Baltimore, Md.*  
 Yehling, Charles Chalice, *St. Louis, Mo.*  
 Zacharias, W. C., *Midland, Mich.*  
 Zeiters, George E., *Shelby, Ohio*

### SAVE THOSE BACK ISSUES

Every so often an unprecedented demand for a particular issue, or an unexpected influx of new subscribers and members puts the editor in the embarrassing position of running out of copies of *Chemical Engineering Progress*. This has happened several times in our short history and if members have copies of any of the following issues, we would be glad to purchase them. The issues which we need and for which we will pay 75 cents each, are: May, 1947; January, 1949; October and November, 1950; February, March, and April, 1951.

All these issues were overprinted to a great extent, but because of features and other demands, single copy sales, etc., they were completely exhausted in a short time.

## YOU CAN STOP liquid carry-over in processing vessels WITH **METEX** MIST ELIMINATORS



The unusually high efficiency with which these *knitted* wire mesh units remove the liquid entrainment that occurs in a wide variety of refining and processing operations has enabled engineers to:

1. Improve product quality and eliminate reruns.
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**METEX** Mist Eliminators can be used *wherever* the problem of liquid entrainment exists. By effecting complete removal of liquids, Mist Eliminators contribute to more efficient and economical processing in such vessels as:

VACUUM PIPE STILL	EVAPORATORS	COMPRESSORS
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### Get the full facts on METEX Mist Eliminators

Write for bulletins giving detailed information—including limiting velocities, pressure drop, efficiencies, etc.



## METAL TEXTILE CORPORATION

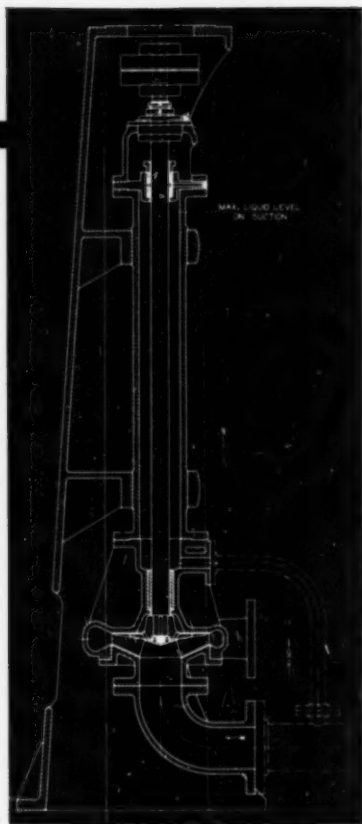
KNITTERS OF WIRE MESH FOR MORE THAN A QUARTER CENTURY



662 EAST FIRST AVENUE ROSELLE, N. J.

(Right) Structural details of Lawrence Vertical Acid Pump.

(Below) Vertical Acid Pump for outside mounting.



## VERTICAL ACID AND CHEMICAL PUMPS

The vertical acid pump illustrated here shows how Lawrence engineers met a particularly difficult pumping problem. Chemical action made it imperative to eliminate packing. While packing is used below the top bearing to confine fumes, it does not come in contact with the acid because the liquid level of the supply tank is kept below that point. This construction is typical of Lawrence advanced engineering design.

Other design features of Lawrence pumps for acids and chemicals include the use of metals and alloys carefully chosen to give the best possible protection against the corrosive and abrasive action of the liquid pumped, as well as structural strength and long wear.

If you have to pump any acid or chemical, hot or cold, write us the pertinent details. No obligation.



Send for bulletin 203-4 for a complete summary of acid and chemical pump data.



**LAWRENCE**  
MACHINE & PUMP CORPORATION  
375 MARKET STREET, LAWRENCE, MASS.

### MARGINAL NOTES

(Continued from page 38)

#### Supplementary Textbook

**Chemical Calculations.** Sidney W. Benson. John Wiley & Sons, Inc., New York. (1952) 217 pp. \$2.95.

*Reviewed by R. P. Shaffer, School of Engineering, Pratt Institute, Brooklyn.*

**T**HIS book is primarily a book of illustrative problems for embryonic chemists. The text starts with chapters on measurement and covers this elementary field very well. The next chapters are devoted to chemical formulae and reactions. Thus one quarter of the text is devoted to the foundation necessary to do problems in energy and chemical changes, properties of gases, valence, solutions, chemical equilibrium, electrical properties of ionic solutions, equilibria in ionic solutions, hydrolysis, oxidation and reduction, and rates of reaction, each of which is taken up in a subsequent chapter.

The illustrative and assigned problems are good and the text is well written and well organized. However, the book is primarily a supplement to texts currently used for freshman and sophomore chemistry. Theoretical considerations are treated as having been covered elsewhere and only a brief summary is presented.

Therefore, the work is of limited value to the engineer. The main usefulness would be as refresher matter for an engineer who has been away from elementary chemical calculations for a long period of time.

#### For Calculating Chemical Engineers

**Linear Computations.** Paul S. Dwyer. John Wiley & Sons, Inc., New York (1951). xi + 344 pp. \$6.50.

*Reviewed by M. T. Cichelli, Eng. Res. Lab., Eng. Dept., Du Pont Co., Wilmington, Del.*

**T**HIS is a well-written book that treats with thoroughness linear problems such as the solution of simultaneous linear equations, evaluation of determinants, calculation of the adjoint and the inverse of a matrix, and the solution of problems involving the characteristic equation. It also contains sections on computation with approximate numbers, errors of linear computation, and the application of computing aids to statistics and to the solution of nonlinear problems. The book was designed primarily for the individual worker, and therefore emphasizes methods that are especially applicable to the modern desk calculator. The author states that, with

techniques now developed, it is feasible to solve linear problems involving up to fifteen or twenty variables on desk computers. More complex computing machines become competitive if a greater number of variables are being handled, if many similar sets of simultaneous equations are to be solved, or, as is true in some cases, if the equations take on a form that is especially applicable to a particular machine. References at the end of each chapter helpfully include the titles of articles and occasionally the author's comments regarding them. Numerous sample calculations are presented and exercise problems are included at the end of each chapter.

This book would make an important addition to the libraries of organizations in which a fair amount of computation is carried out by desk and machine computers. Mathematicians and research workers who frequently have the problem of solving simultaneous linear equations will find it without parallel in this field. It seems likely that only those chemical engineers who are actively engaged in mathematical computation of this type would be interested in procuring a copy for their personal use.

#### Applications Before Principles!

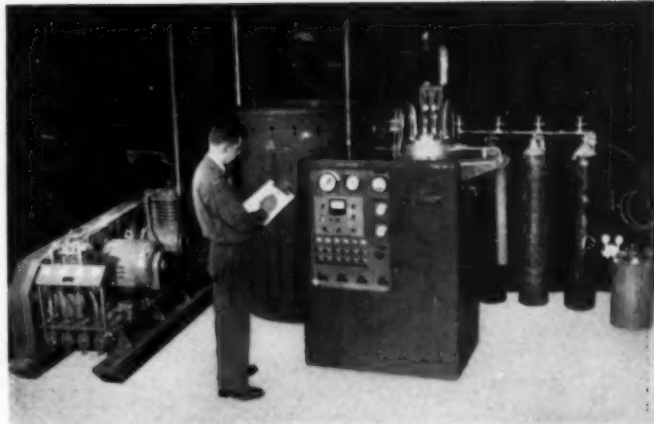
**Elementary Heat Power**, 2nd ed., H. L. Solberg, O. C. Cromer, and A. R. Spalding, John Wiley & Sons, Inc., New York. (1952). 624 pp. \$6.50.

*Reviewed by Joseph Joffe, Prof. Chemical Engineering, Newark College of Engineering, Newark, N. J.*

**E**LEMENTARY Heat Power" is a college text in the fundamentals of heat-power equipment pitched to the sophomore level. The descriptive material in the text serves to introduce the student to basic types of equipment and their functions. Extensive use is made of material and energy balances in the presentation of principles and in problems. Since little mention is made of the second law of thermodynamics, much in the performance of heat-power equipment is of necessity left only partly explained.

This book may serve a useful purpose in introducing the mechanical engineering student to applied thermodynamics by easy stages. The reviewer, however, has serious qualms about teaching applications ahead of principles.

To the chemical engineer who seeks information on the performance of heat-power equipment and who does not wish to lose himself in a maze of detail this work commends itself as a useful reference.



## SOLID STATE PHYSICS

### Cryogenic

- Nuclear resonance experiments
- Superconductivity
- Resistance minima in metals at low temperatures
- Second-sound in liquid Helium II
- Thermal conductivity and specific heat of solids
- Phase changes of the second order

... are a few of the studies utilizing the ADL Collins Helium Cryostat—a complete installation providing 4 liters of liquid helium per hour and capable of maintaining test chamber temperature from ambient to  $-271^{\circ}\text{C}$ .

### Magnetic

- Magnetic susceptibility of metals and alloys
- Paramagnetic resonance experiments
- Magnetic properties of many materials
- Solidification and crystallization studies

... are examples of work aided by the ADL Electromagnet. Variable air gap, interchangeable pole pieces (up to 11" in diameter) and fields of over 40,000 gauss with only 20 KW power input, add up to a remarkably versatile electromagnet for a wide variety of research projects.



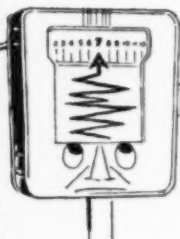
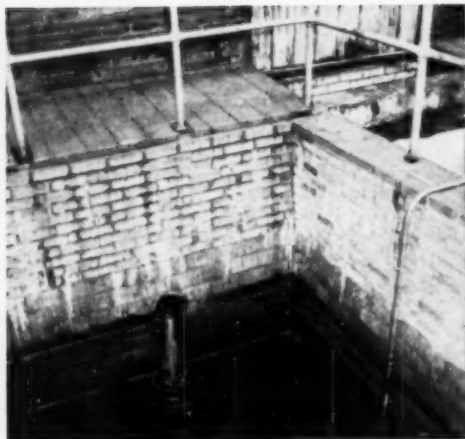
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Bulletin CPC-1, Collins Helium Cryostat  
Bulletin CPM-1, ADL Electromagnet



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## When the pointer can't make up its mind...specify → **Pennsalt Furan Cement**

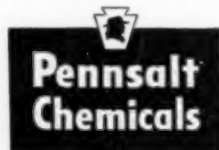
for your corrosion-proof mortar

If you are the process engineer in a typical chemical unit, facing alternate acid-then-alkaline conditions, then you want to know how best to handle *both* in corrosion-proof equipment.

The answer is Pennsalt Furan Cement mortar, according to many other plants who have this same problem. Matter of fact, we use it ourselves in our own plants which make everything from household lye to elemental fluorine. And here's why Pennsalt Furan Cement gets the nod:

- Resistant to alkalis, most acids, solvents, greases, organics, salts ... to temperatures of 350-375°F.
- Forms dense, hard, non-porous mortar with excellent abrasion resistance and adhesion.
- Permits narrowest practical widths of joints.
- Longer-than-average working time, easier handling.
- Chemical setting, allowing hardening in confined areas.
- Stable—won't freeze in winter or become viscous in summer.
- Non-toxic, not conducive to dermatitis, not a fire hazard. Contains no vaporizing solvent.

As you know, users of Pennsalt Cements gain the added benefit of Pennsalt's Corrosioneering Service—built around many years of hard-bitten experience in applying corrosion-proof materials in severe chemical environments. Why not write and find out how Pennsalt Furan Cement may answer a corrosion problem of yours? Corrosion Engineering Products Dept., Pennsylvania Salt Manufacturing Co., Philadelphia 7, Pa.



## NEWS

(Continued from page 48)

### POLONIUM FOR SALE

Reactor-produced radioactive polonium-210 may now be purchased at Oak Ridge for research activities according to the isotopes division of the Atomic Energy Commission.

Polonium is the first reactor-produced radioisotope to be sold which emits alpha particles. It can be used also as a source of high energy neutrons.

The polonium announcement marked the anniversary of the isotope program and Oak Ridge National Laboratory reported that more than 35,000 shipments have been made since Aug. 2, 1946, to users in forty-six states and thirty-three foreign countries. Several thousand additional shipments were made from other sources, such as Brookhaven National Laboratory, Argonne National Laboratory and commercial processing concerns.

The newly available polonium will be used by research groups for physical and biological investigations, and in oil-well logging and for ionization sources.

Polonium can be bought at Oak Ridge National Laboratory in two forms. When it is to be used as a neutron source, the polonium will be mixed with beryllium and enclosed in a cylinder of nickel, about 3/4-in. diam. As an alpha source, the polonium will be placed on a strip of platinum. Polonium-210 produced in a reactor by neutron bombardment of bismuth is of higher purity than polonium derived from the radioactive decay of radium.

### PFADLER ENDOWS UNIV. OF ROCHESTER

The Pfadler Co. established an unrestricted \$45,000 Pfadler Endowment Fund at the University of Rochester, recently. The gift is unusual in that no restrictions have been placed on its use. Edward G. Miner, chairman of the board of The Pfadler Co., explained that, "A university, like a business enterprise, constantly faces new conditions and contingencies. In order to be able to adapt its course to changing needs, it must have unrestricted resources on hand."

Dr. Cornelis W. de Kiewiet, President of the University of Rochester, in accepting the gift declared, "it helps to meet one of our most urgent needs—additions to the unrestricted endowment." The Pfadler Co. has made contributions to the university in the past, such as grants for fellowships, he noted.

Mr. Miner pointed out that it is of mutual interest to business and higher education to keep institutions like the university independent of public support and control.

## TOP MANAGEMENT PROBLEMS CHANGING

Major problems facing top management in industry are changing at an almost unprecedented rate according to Harold F. Howard, president of a Detroit industrial and management engineering company.

An annual study of management's top ranking problems made by the Howard company, reveals important differences from just one year ago, "and," Howard said, "any list of the most pressing problems of just three years ago is obsolete today. Our own check list for top management has not only been completely revamped, but we have found it necessary to expand it approximately 25%."

Now rated as of primary importance, according to the Howard list, are: (a) executive selection and development, (b) fast acting accounting systems, (c) flexible budget controls, (d) labor standards that keep up with method changes, (e) operating costs that are in line with competition and (f) constant product development.

He continued:

Among today's top problems not considered as serious a year ago are executive appraisal and development programs, inspection programs that aid sales, market research for new products and rigid inventory controls.

Many of these problems deal directly or indirectly with 'sales,' a subject that should be foremost in the minds of most top managements in industrial companies today, according to our findings.

Howard said that "sales" are rapidly becoming a top problem in industry as a direct result of higher taxes on both producer and consumer, layoffs caused by strikes, shrinkage in the defense program, limitations on commercial plant expansion and modernization, and an impending shift to a buyer's market.

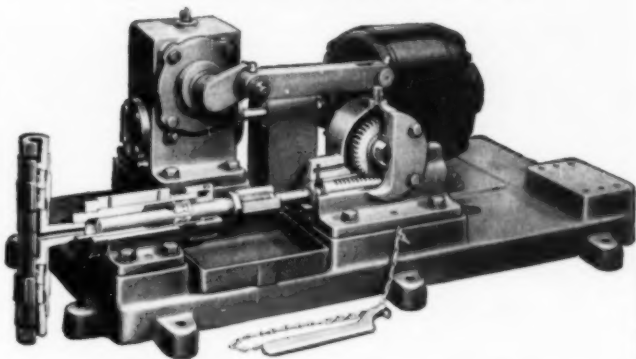
## WILSON SAYS SHALE GAS TOO COSTLY

Robert E. Wilson, chairman of the board, Standard Oil Company (Ind.), last month issued a statement calling the current proposal by Interior Secretary Chapman for making synthetic fuel from coal or shale, premature and costly.

"The early construction of commercial plants for making gasoline and other liquid fuels from coal or shale," said Wilson, "as urged by Secretary Chapman, would be most premature. Estimates show that the cost to the consumer of products made either from coal or from shale would be substantially higher than the cost of the same products made from petroleum. Shale is presently much more attractive than coal. Even to approach an economic

(Continued on page 56)

## For precisely controlled metering and proportioning of small volume flows...



## ... the HILLS-McCANN A "U" Type Proportioning Pump

• The Hills-McCanna "U" Type Pump is designed to continuously meter and proportion small flows of the order of 0.10 to 24 gallons per hour per feed. Its accuracy and reliability suit it for research, pilot plant operation and full scale processing alike. The "U" type pump is suitable for batch or continuous operations.

Typical examples of "U" type pump applications include:

- Continuous addition of air entraining agents during cement manufacturing operations.
- Continuous injection of internal phosphate treatment and sodium sulphite oxygen scavenging in boiler plant water treatment.
- Injection of gasoline gum inhibitors into finished gasoline.
- Proportioning low molecular weight polymers and catalyst solution in resin research.



The new "U" Pump Catalog, UP-52, gives full information on the "U" type pump plus extensive application data including specific service recommendations for handling over 300 substances. Write for your copy, today. HILLS-McCANN A CO., 2438 W. Nelson St., Chicago 16, Ill.

## HILLS-McCANN A

*metering and proportioning pumps*

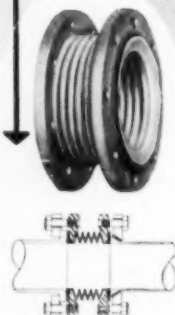
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Designed for 25 lb. pressure and temperatures from -110°F. to 500°F., there are types for conical-end glass fittings, glass lined assemblies and for standard 125 lb. or 150 lb. A.S.M.E. integrally-gasketed flanges. Ask for catalog No. 212. For special conditions supply pertinent data.

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FABRICATORS OF "TEFLON", "KEL-F" AND OTHER FLUOROCARBON PLASTICS

(Continued from page 55)

operation, however, the shale installation would have to be on a tremendous scale and would involve a large pipe line to consuming centers, and major expenditures for housing and water supply," he continued.

Wilson also said the oil industry experienced no reduction in the rate of finding petroleum. "In fact," he claimed, "just the reverse is the case. The oil industry is finding oil faster than it is using it. There are several other factors that push far into the future the time when we will need oil from coal or from shale. As the report to the President by the President's Materials Policy Commission points out, methods of finding and producing oil are constantly being improved. Moreover, in addition to the 32 billion barrels generally counted as our proved reserves, we know the location of more than 100 billion barrels, in existing fields not now recoverable by present methods at current price levels. Of this additional oil, perhaps 65 billion may eventually be recovered by the secondary methods of recovery—which are constantly being developed."

Mr. Wilson remarked further:

As still another cushion against future shortage, large amounts of residual fuel oil could be hydrogenated to make gasoline and other more valuable products. The logical

way for coal to begin to supplement oil reserves is under the boilers of industrial power stations, where it is almost competitive with oil at the present time.

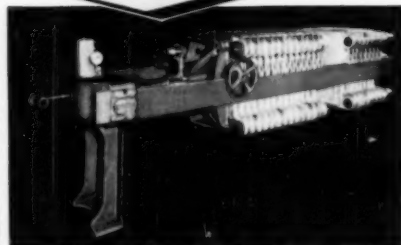
We must remember that no one can foresee which of the processes for making synthetic gasoline will ultimately prove most economic. A year ago Secretary Chapman wanted to spend approximately a half-billion dollars on coal hydrogenation plants. Now the emphasis seems to be on shale, and Secretary Chapman also points out that a low-cost method of coal gasification might well lead to the Fischer-Tropsch process. Since it will be much more than a decade before synthetic fuel from any of these routes can really compete with petroleum, the interim should obviously be spent on pilot-plant and other small-scale development work, aimed at improvement of the processes for converting both coal and shale. Large-scale plants would probably be obsolete before they were completed, and would cost many times as much as an intelligently planned research program . . .

## PHENOL PLANT FOR WEST COAST

Monsanto Chemical Co. has begun construction of a plant on an 86-acre site at nearby Avon, Calif., for the manufacture of phenol, according to Irving C. Smith, general manager of the company's Western division.

The new plant, which is expected to be in operation by early 1954, will be jointly built and operated by Monsanto's Western and organic chemicals divisions.

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## LOCAL SECTION

### NEW YORK

This Section will hold its annual symposium at the Hotel McAlpin, Oct. 21. This will be an all-day affair beginning about 9 A.M. and continuing until 4:30 P.M. Two topics will be covered: Adsorption and Cost Estimation.

The tentative program for the Adsorption symposium is as follows:

**What is Adsorption?**—Robert E. Treyball, Prof. Chem. Eng., N.Y.U.

**Fundamentals of Adsorption**—Leon Lapidus, Res. Engr., The James Forrestal Research Center, Princeton, N. J.

**Design Aspects**—Robert Merims, Design Engr., Foster-Wheeler Corp.

**Adsorption from the Gas Phase**—Frank Browning, Asst. Mgr., special products division, Carbide and Carbon Chemicals Co.

**Adsorption from the Liquid Phase**—Walter A. Helbig, Chem. Engr., Darco dept. Atlas Powder Co.

**What's Ahead in Adsorption**—C. L. Mantell, Consultant, Head of Department, Chem. Eng., College of Engineering, Newark, N. J.

The tentative program for the Cost Estimation symposium is as follows:

**The Dollar as an Engineering Unit**—Sydney Steele, Atlas Powder Co.

**Cost Control by Kilowatts**—D. E. Pierce, chief engr., General Aniline & Film Corp.

**Where Cost Estimates Go Sour**—Not announced.

**Engineering and Other Indirect Costs of Process Plants**—J. P. O'Donnell and J. J. Mahoney, Consulting Engrs., New York.

**The Cost of Packaging Chemicals**—R. F. Uncles & T. Carter, American Cyanamid Co.

**The Cost of Shipping Chemicals**—Stuart P. Smith, Jefferson Chemical Co.

This Section will hold a meeting Oct. 2, 1952, at the Brass Rail Restaurant, 521 Fifth Avenue at 6 P.M. Paul Alsbaugh is the scheduled speaker and his subject will be "Coal Hydrogenation."

### SOUTHERN CALIFORNIA

A meeting will be held Sept. 16 at Old Dixie Barbecue, Los Angeles. The featured speaker will be F. S. Sawyer, assistant to the director of research, Stanford Research Institute, whose topic will be "What a Research Institute Means to the West." Dr. Sawyer will

(Continued on page 59)

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## PART II\*

M. C. THRODAHL, R. VOORHEES, and A. G. DRAEGER

**Financing.** The Unit Operations Committee recommended, and the Executive Committee approved, a plan whereby each lecturer would be paid for his entire traveling expenses plus a small honorarium. (Most of the lecturers contacted were members of A.I.Ch.E.). A fee of \$6.00 for eight lectures was charged for paid-up members of the Section and a fee of \$7.50 was charged to all others. The size of this fee was established to break even for the operation of the two courses and actually the receipts exceeded the expenses by approximately \$17.00, or within 1% of the total cost of the courses. A course prospectus was passed out to section members first, and a deadline set for their first refusal before opening the class to other interested persons.

**Results.** Results of the Distillation and Heat Transfer courses will have different values to each participant. For some, these courses were a fresh but intensive approach to the theory—perhaps from an “appreciation” point of view only. Others found real stimuli for new approaches to design problems employing distillation and/or heat transfer.

As would be expected, the classes in distillation and heat transfer were composed predominantly of chemical engineers, but roughly 10% of the participants were engineers of other kinds, and some 4% were chemists. The division as to type of work in which each class member was engaged was roughly as follows: Production, 50%; Engineering, 30%; Research and Development, 20%. The median age of each of the groups was 31 years, with approximately 65% of the class in the 26-33-year age group. Approximately 25% of those in each class possessed advanced degrees in chemical engineering.

The paid-up membership of 148 for Distillation and 119 for Heat Transfer out of a total membership of approximately 300 indicates an unusual degree of interest in further professional development on the part of most of the younger members of the Institute.

It is felt that the quality and caliber

of the lectures generously met the standards of the Institute and provided real benefit and stimulation for the participating class members.

**Future Program.** The exceptionally enthusiastic reception of and participation in the Distillation and Heat Transfer courses gave the Committee encouragement to consider future study courses for local section sponsorship. However, the median age of 31 indicated that many older Institute members may not have found it advantageous to participate in Unit Operations courses because of the more or less executive nature of their professional responsibilities. Furthermore, there were some indications that the more popular unit operations might well be continued into another year.

The Committee accordingly drew up a list of possible courses of more general interest in addition to unit operations and unit processes which were to be considered by Section members in all phases of chemical engineering. For this next survey the entire membership of the Section was covered, and on the basis

of results from that survey the following courses were found to be in greatest demand: Speed Reading, Chemical Thermodynamics, Chemical Corporation Finance, Chemical Economics, Technical Writing, and Chemical Kinetics. It is somewhat surprising to note that these courses were preferred when offered on the same slate as the complete list of unit operations and unit processes. Therefore, the present Unit Operations Committee has recommended to the Executive Committee of the Charleston Section that the aforementioned general courses be seriously considered for sponsorship during the next year.

### Literature Cited

1. Anon., *Chem. Eng. Progress*, **48**, No. 7, 37 (1952).
2. Brown, G. G., *Chem. Eng. Progress*, **47**, No. 3, 46 (1951).
3. Bruce, D. S., *Chem. Eng. Progress*, **48**, No. 3, 60 (1952).
4. Kobe, K. A., *Ibid.*, **47**, No. 9, 48 (1951); **48**, No. 8, 58 (1952).
5. Scoville, L. P., *Ibid.*, **47**, No. 12, 52 (1951).

### LECTURERS AND SUBJECTS

TABLE 1.—ADVANCED DISTILLATION\*

Lecturer	Subject
E. H. TenEyck, DuPont Co. Belle, W. Va.	Introduction and review of fundamental distillation theory
E. H. TenEyck	Binary mixtures
J. A. Gerster, University of Delaware	Treatment of non-ideal mixtures
E. H. TenEyck	Azeotropic and extractive distillation
W. C. Edmister, Carnegie Institute of Technology	Multicomponent distillation—I
W. C. Edmister	Multicomponent distillation—II
C. E. McConnell, Jr., Carbide & Carbon Chemicals Co. South Charleston, W. Va.	Bubble cap column design
John G. Dobson, The Foxboro Co., Foxboro, Mass.	Instrumentation of still columns

\* Eight lectures in all from Feb. 18, 1951-Feb. 14, 1952.

TABLE 2.—HEAT TRANSFER\*

Robert Rothfus, Carnegie Institute of Technology	General considerations; conduction of heat
Robert Rothfus	Flow of fluids; simultaneous heat and momentum transfer in fluids
Robert Rothfus	Lecture 2, continued; simultaneous heat and mass transfer in fluids
Robert Rothfus	Lecture 3, continued; radiant heat transmission
Kenneth O. Beatty, North Carolina State College	Unsteady state heat transfer
Charles F. Bonilla, Columbia University	Free convection transfer processes
Daniel A. Donohue, The Lummus Co.	Practical aspects of heat exchanger design
J. H. Rushton, Illinois Institute of Technology	Heat transfer in agitated vessels

\* Eight lectures in all from Feb. 20, 1952-May 28, 1952.

\* Part I of this article was run in August, page 58.

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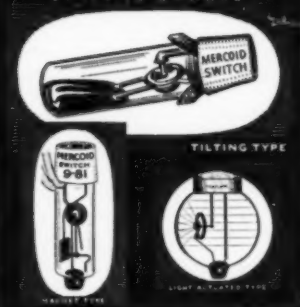
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## LOCAL SECTION NEWS

(Continued from page 57)

discuss the prime responsibilities of S.R.I. in serving Western industry. At the Aug. 19 meeting held at the Midland Rubber Corp., Jack Waley, a member of the plant technical department, gave a short talk on GRS synthetic rubber, emphasizing particularly the new processes for cold rubber, after which several small groups toured the facilities. At a previous meeting, at the Rio Hondo Country Club, Donald G. Hunt, training director for the Proctor and Gamble Co., talked on Employee Education in the Fundamentals of the American Business System. The talk was highlighted by a unique card display and a question-and-answer period followed.

Reported by G. S. Peterson

## SOUTH TEXAS

The seventh annual technical meeting of this Section will be held in the Rice Hotel, Houston, Tex., Oct. 24, 1952, as announced in the August issue of "C.E.P." In the morning there will be a symposium on fractionating tray developments and a student session running concurrently; in the afternoon, a symposium on production and purification of aromatics and a general session, also running concurrently. At the afternoon symposium session two additional papers will be included. For the evening a cocktail party and banquet are scheduled. Sidney Kirkpatrick will be the evening's speaker.

The preliminary program follows:

### Symposium on Fractionating Tray Developments

(Morning Session—No. 1)

A Design Method for Bubble Trays—G. T. Atkins, Humble Oil and Refining Co., Baytown, Tex.

Perforated-Plate Distillation Columns—F. Drew Mayfield, Walter L. Church, Jr., A. C. Green, D. C. Lee, Jr., and R. W. Rasmussen—Celanese Corporation of America, Bishop, Tex.

The Kaskade Tray in Its Present State of Development—G. C. Thrift, Koch Engineering Co., Inc., Wichita, Kan.

The Turbogrid Distillation Tray—Shell Development Co., Emeryville, Calif. To be presented by Earl Manning, Jr., Houston Research Laboratories, Shell Oil Co., Houston.

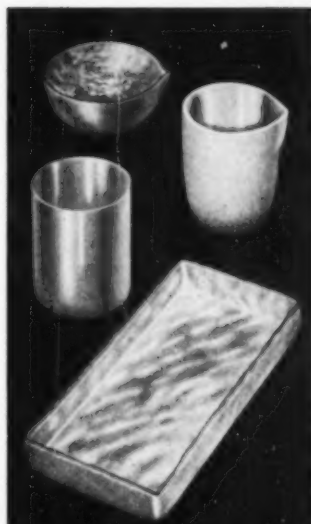
### Student Session

(Morning Session—No. 2)

Introduction—C. G. Kirkbride, Houdry Process Corp., Philadelphia, Pa.

Economics in Engineering—Serge B. Jurenev—Continental Oil Co., Houston.

(Continued on page 61)



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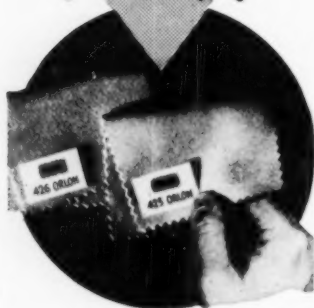
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## FUTURE MEETINGS AND SYMPOSIA OF A.I.Ch.E.

*Chairman of the A.I.Ch.E. Program Committee*

Walter E. Lobo, The M. W. Kellogg Co., 225 Broadway, New York 7, N. Y.

### MEETINGS

**Annual**—Cleveland, Ohio, Hotel Cleveland and Carter Hotel, Dec. 7-10, 1952.

**Technical Program Chairman:** R. L. Savage, Dept. of Chem. Eng., Case Inst. of Tech., Cleveland 6, Ohio.

**Biloxi, Miss.**, Buena Vista Hotel, Mar. 8-11, 1953.

**Technical Program Chairman:** Norman A. Spector, Vitro Corp., 233 Broadway, New York 7, N. Y.

**Toronto, Canada**, Royal-York Hotel, April 26-29, 1953.

**Technical Program Chairman:** Brymer Williams, Dept. of Chem. and Met. Eng., University of Michigan, Ann Arbor, Mich.

**San Francisco, Calif.**, Fairmont and Mark Hopkins Hotels, Sept. 13-16, 1953.

**Technical Program Chairman:** R. W. Moulton, Head, Dept. of Chem. Eng., University of Washington, Seattle, Wash.

**Annual**—St. Louis, Mo., Hotel Jefferson, Dec. 13-16, 1953.

**Technical Program Chairman:** R. M. Lawrence, Monsanto Chem. Co., St. Louis 4, Mo.

### SYMPOSIA

#### Applied Thermodynamics

**Chairman:** W. C. Edmister, California Research Corp., Richmond, Calif.

**Meeting**—Cleveland, Ohio

#### Human Relations

**Chairman:** R. L. Demmerle, General Aniline & Film Corp., 230 Park Ave., New York, N. Y.

**Meeting**—Cleveland, Ohio.

#### Modern Statistical Methods in Chemical Engineering

**Chairman:** C. Daniel, Engineering Statistician, 116 Pinehurst Ave., New York 33, N. Y.

**Meeting**—Cleveland, Ohio.

#### Filtration

**Chairman:** F. M. Tiller, Dir., Div. of Eng., Lamar State College of Technology, Beaumont, Tex.

**Meeting**—Cleveland, Ohio

#### High Pressure

**Chairman:** E. W. Comings, Head, School of Chem. & Met. Eng., Purdue University, Lafayette, Ind.

**Meeting**—Cleveland, Ohio.

#### Mineral Engineering Techniques for Chemical Engineers

**Chairman:** N. Morash, Titanium Div., National Lead Co., P. O. Box 58, South Amboy, N. J.

**Co-Chairmen:** T. S. Leary, Calco Chem. Div., Bound Brook, N. J., and D. W. Oakley, Metal & Thermit Corp., Carteret, N. J.

**Meeting**—Biloxi, Miss.

#### Chemical Engineering in Hydrometallurgy

**Chairman:** John D. Sullivan, Battelle Memorial Institute, Columbus, Ohio.

**Co-Chairman:** John Clegg, Battelle Memorial Institute, Columbus, Ohio.

#### Fluid Mechanics

**Chairman:** R. W. Moulton, Head, Dept. of Chem. Eng., University of Washington, Seattle, Wash.

#### Absorption

**Chairman:** R. L. Pigford, Div. of Chem. Eng., Univ. of Delaware, Newark, Del.

Authors wishing to present papers at a scheduled meeting of the A.I.Ch.E. should first query the Chairman of the A.I.Ch.E. Program Committee, Walter E. Lobo, with a carbon copy of the letter to the Technical Program Chairman of the meeting at which the author wishes to present the paper. Another carbon should go to the Editor, F. J. Van Antwerpen, 120 East 41st Street, New York 17, N. Y. If the paper is suitable for a symposium, a carbon of the letter should go to the Chairman of the Symposia. Instead of the Chairman of the Technical Program, since symposia are not scheduled for any meeting until they are complete and approved by the national Program Committee. Before authors begin their manuscripts they should obtain from the meeting Chairman a copy of the Guide to Authors, and a copy of the Guide to Speakers. The first book covers the preparation of manuscripts, and the second covers the proper presentation of papers at A.I.Ch.E. meetings. Presentations of papers are judged at every meeting and an award is made to the speaker who delivers his paper in the best manner. Winners are announced in *Chemical Engineering Progress*, and a scroll is presented to the winning author at a meeting of his local section. Since five copies of the manuscript must be prepared, one should be sent to the Chairman of the symposium and one to the Technical Program Chairman of the meeting, or two to the Technical Program Chairman if no symposium is involved and the other three copies should be sent to the Editor's office. Manuscripts not received 70 days before a meeting cannot be considered.

## LOCAL SECTION NEWS

(Continued from page 59)

**Politics and Civic Activities**—H. K. Eckert—Monsanto Chemical Co., Texas City, Tex.

**Putting Music and Drama in Their Place**—George B. Gibbs, Petroleum Refiner, Houston.

**Law and the Engineer**—C. M. Hudspeth, DeLange and Hudspeth, Attorneys, Houston.

**Investment Planning**—G. Seth Innis, Commercial and Industrial Life Insurance Co., Houston.

**Public Speaking**—Walter D. Kelsey—Houston Association of Credit Men, Inc., Houston.

### Symposium on Production and Purification of Aromatics

(Afternoon Session—No. 3)

**The Arosorb Process for Odorless and Highly Aromatic Solvents**—Earl R. Weatherly and George H. Shimp—Sun Oil Co., Marcus Hook, Pa.

**Shell Extractive Distillation Process for Recovery of High-Purity Aromatics**—C. L. Dunn and G. E. Liedholm—Shell Development Co., Emeryville, Calif. To be presented by Ray A. Wilson, Houston Research Laboratories, Shell Oil Co., Houston.

### General Session

(Afternoon Session—No. 4)

**Acetylene from Hydrocarbons by the Wulff Process**—Theodore Weaver—Fluor Corp., Ltd., Los Angeles, Calif.

**The Application of Radioisotopes to Chemical Engineering**—Jerome Kohl, Tracerlab, Inc., Berkeley, Calif.

**Rapid Reading**—L. T. Callicott—University of Houston, Houston.

**Design of Tubular Process Heaters from the Inside of the Tubes**—L. A. Mekler, Petro-Chem. Process Co., and Petro-Chem. Development Co., Palo Alto, Calif.

## SULFUR PRODUCTION AT WHITING

Standard Oil Company (Indiana) has started production of sulfur in a new plant at its Whiting (Ind.) refinery which will help meet a world-wide shortage of this defense material.

Sulfur is essential to many phases of petroleum refining and to most basic industries either in its elemental form or after conversion to sulfuric acid. Most of the Whiting production of 55 tons per day of sulfur will be converted to sulfuric acid on existing plant facilities for use in alkylation and treating operations.

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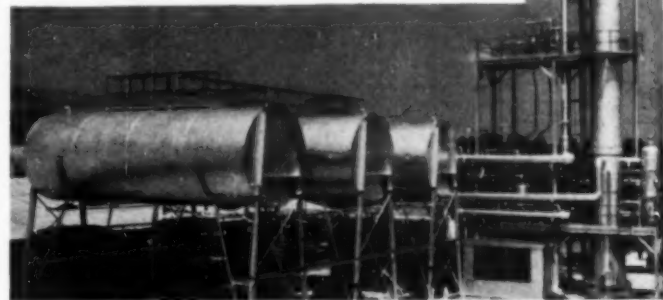
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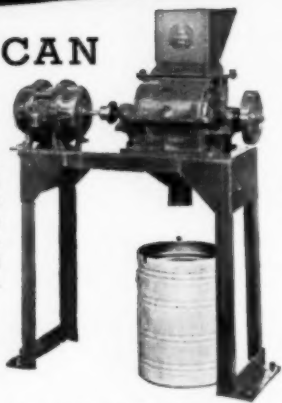
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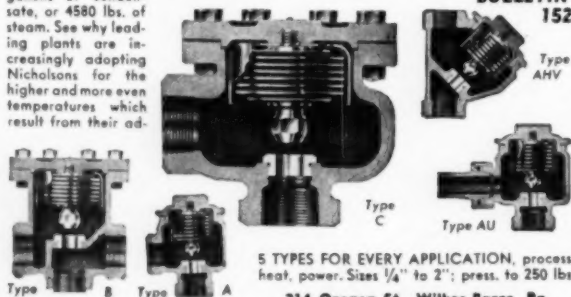
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## PEOPLE

Jesse Werner has been named director of commercial development of



the General Aniline works division of General Aniline & Film Corp., New York. In this capacity he will be in charge of all market research and development activities concerned with GAF's line of non-dyestuff chemicals.

Dr. Werner, who has been with General Aniline since 1938, previously served as technical assistant to the vice-president in charge of operations. Prior to that he was assistant manager in the process development department of GAF's Grasselli, N. J. plant. He received his Ph.D. degree from Columbia University in 1938.

Luther R. Hill, president of Process Designs, Inc., has been appointed by Houdry Process Corp., Philadelphia, Pa., as consultant on catalytic cracking and reforming operations. Mr. Hill, a graduate chemical engineer of the University of Texas, spent twenty-five years in various phases of the petroleum industry prior to establishing Process Designs, Inc., at Ridgewood, N. J., this year.

William E. Ranz, assistant professor of chemical engineering at the University of Illinois, Urbana, Ill., is away on leave of absence on a National Science Foundation Fellowship at Cambridge University. Dr. Ranz received his Ph.D. degree at the University of Wisconsin, and has been on the staff of the Engineering Experiment Station at Illinois for the past year.

Warren M. Berrell has been named to direct economic studies of new manufacturing fields for J. T. Baker Chemical Co., Phillipsburg, N. J. He joined Baker from The Pfaunder Co., Rochester, N. Y., where he was New York City sales representative. From 1947 through 1949 he operated his own chemical engineering consulting company in Boston. For three years prior to that Berrell was in charge of process engineering. Berrell was senior chemical engineer at Merck from 1941-1944, and was responsible for the design of much of the firm's penicillin, sulfa, and vitamin plants. He is a graduate of Worcester Polytechnic Institute.





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**D. S. Dinsmoor**, vice-president in charge of research and development, has recently been appointed to the board of directors of American Potash & Chemical Corp., Calif. Dinsmoor, who joined the company in 1948, formerly was vice-president of the Monsanto Chemical Co. and served as general manager of the Merrimac division at Everett, Mass. He received a B.S. degree from Dartmouth and an A.M. degree from Harvard University.



### MUELLER ADVANCED BY MONSANTO CHEM. CO.

The appointment of Robert K. Mueller of Hampden, Mass., as general manager of Monsanto Chemical Co.'s plastics division has been announced.

Mueller was graduated from Washington University in 1934 with a B.S. degree in chemical engineering. A year later he received an M.S. degree in chemistry from Michigan University.

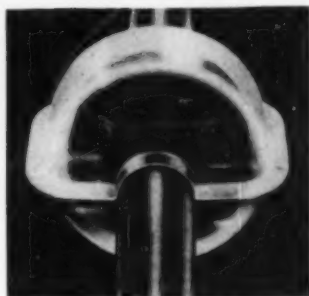
Before going to Monsanto in 1935 as a control chemist at the John F. Queeny plant in St. Louis, Mueller was employed by the Sinclair Company at its East Chicago refinery as a chemist. In 1938, he was transferred to Monsanto's subsidiary Shawinigan Resins Corp. plant at Springfield, and in 1939 went to the company's plastics division there. In 1940, he was promoted to operating superintendent at Springfield, and in 1942 was transferred to Karnaack, Tex., as a member of the Longhorn Ordnance Works production staff. At the end of the war, he returned to Springfield and subsequently became assistant general manager.

**Wesley S. Coe's** appointment as assistant factory manager of the Naugatuck, Conn., plant of Naugatuck chemical division, United States Rubber Co. was recently announced. Dr. Coe joined the company at its general laboratories in Passaic, N. J., in 1936 after receiving his doctor's degree in chemistry at the University of Illinois. Immediately prior to his new appointment, he was chemical production superintendent and assistant to the factory manager.

(More News About People on page 64)



# NEW



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**John Crowther**, associated with Stauffer Chemical Co. for seven years and director of the Eastern division research at Chauncey, N. Y., has been appointed to the position of assistant sales manager. Before joining Stauffer, he was a Major in the U. S. Air Force. Prior to the war he was with The M. W. Kellogg Co. Mr. Crowther is a graduate of the Massachusetts Institute of Technology with a B.S. degree in chemical engineering.



**H. A. Hashbarger**, development manager of Monsanto Chemical Co.'s foreign department, has joined the development department of the company's organic chemicals division. He has been with the company since 1937. A graduate of the University of Illinois with a B.A. degree in chemical engineering, he was first employed in the analytical laboratory of the John F. Queeny plant in St. Louis. In 1940 he became a member of the plant's production department and two years later was assigned to the Longhorn Ordnance Works at Karnack, Tex., which Monsanto operated for the government during World War II. Subsequently, he went to Dayton, Ohio, as a member of the research team working on rocket propellants and the following year was assigned to the company's plant at Nitro, W. Va., as a production supervisor. In 1948, he returned to St. Louis as development manager of the company's foreign department.

**L. C. Chamberlain**, manager of research for the plastics department, The Dow Chemical Co., Midland, Mich., since 1945, has been named assistant to the director of research, R. H. Boundy. Chamberlain joined the Dow company in 1928 after graduating from Tulane University, and entered the physical research laboratory. He became assistant director of the laboratory in 1941 and remained there until 1945 when he was placed in charge of the company's plastics research activities. He has been active in numerous Dow process developments, including iodine, bromine from sea water, and the Dowell process for acidizing oil wells.

**David J. Porter** was formerly assistant technical director at Westvaco chlorine products division of Food Machinery & Chemical Corp., South Charleston, W. Va. He is now staff supervisor in the research and development department of Diamond Alkali Co., located in the Diamond Technical Center, Painesville, Ohio.

**Philip Miller's** appointment as laboratory director for Walter Kidde nuclear laboratories was recently announced. Formerly associated with the Tennessee Valley Authority, Dr. Miller was in charge of pilot plant and other process development work in inorganic chemicals and he took a leading part in technical developments that resulted in widespread use of ammonium nitrate as a fertilizer material. For his work in the development of a process for extraction of alumina from clay, Dr. Miller and J. H. Walthall received the William H. Walker Award from the A.I.Ch.E. in 1946. He has been engaged in process engineering and development in the atomic energy field for the past five years.

**R. Marvin Garrett** has recently resigned as a sales engineer for the Taylor Instrument Co., at the Los Angeles sales office, and is now in charge of sales and a partner in the Silver Plastic Co. Garrett graduated from Ohio State University in 1943 with a bachelor's degree in chemical engineering. Prior to his service in the U. S. Navy, during World War II, he worked for the Rohm & Haas Co., Bristol, Pa. After the war graduate work at the University of Chicago, Ohio State University, and the University of California led to a degree of Master of Business Administration. In 1948, Garrett became associated with Taylor Instrument.

**Carlyle J. Stehman** has been named organic process group leader at The Chemstrand Corp., Decatur, Ala. He was previously engaged in fiber research at Chemstrand's laboratory at Dayton. Dr. Stehman was formerly a chemist and group leader for Monsanto Chemical Co. at Dayton for fifteen years, and before that he was a research assistant for Pennsylvania Grade Crude Oil Association, and Pennsylvania State College. He holds a B.A. degree from the University of Illinois, and a Ph.D. degree in chemistry from Pennsylvania State College.

**John C. Garrels, Jr.**, a graduate of the University of Michigan, has been selected to attend the 22nd Advanced Management Program at Harvard University Graduate School of Business Administration. Mr. Garrels has been production manager of the plastics division of Monsanto Chemical Co., St. Louis, Mo., since 1950. Prior to that, he had been plant manager at Springfield for two years. He began with Monsanto as plant buyer at Monsanto's Trenton (Mich.) operation, later becoming plant superintendent of the Chemical Warfare Service operation at Monsanto, Tenn. In 1946, he became general manager of Laucks, Inc., a Monsanto subsidiary at Lockport, N. Y.

K. A. Smith is now director of the light oils division of Sinclair Research Laboratories, Inc., Harvey, Ill. Upon graduation from the University of Wisconsin in 1943 with a B.S. degree in chemical engineering, he began his career with Sinclair in the research and development department. First in the operation of pilot plants, where he did much work during the war on the research and development of new aviation gasolines, he was also connected with the process design division of the research and development department. In 1946, he returned to the University of Wisconsin and in 1948 he was awarded his Ph.D. in chemical engineering, whereupon he returned to Sinclair. In his new position Doctor Smith will cover the direction of research and development work on processes and products in light oils.

J. Paul Ekberg was appointed technical representative for Monsanto Chemical Co.'s Washington (D.C.) office. He had been assistant manager of petroleum chemical sales for the organic chemicals division in St. Louis, Mo. Ekberg graduated from Yale University with a B.E. degree in chemical engineering in 1940, and joined Monsanto as a chemist in the analytical laboratory of the company's John F. Queeny plant. He later served as an assistant production supervisor and a sales engineer before becoming assistant manager of petroleum chemical sales in 1951, the position he held up until his recent appointment.

Donald R. Guthrie has been appointed executive engineer in charge of engineering research at the Minnesota Mining & Manufacturing Co. He joined the company as a research chemist in 1939 and was made a division engineer in 1944. In his new position he will organize an engineering research group consisting of three sections: chemical engineering, machine development and instrument engineering. The purpose of the new group will be to provide specialized engineering assistance to engineers in the company's various product divisions. He received his degree in chemical engineering from the University of Iowa in 1938.



#### Correction

In the August issue, page 71, it was stated that John Marshall was manager at Shell's Wood River (Ill.) refinery. His position is head of the experimental laboratory at Wood River.

(More about people on page 67)

## HIGH VACUUM PUMPS REQUIRE CLEAN OIL...



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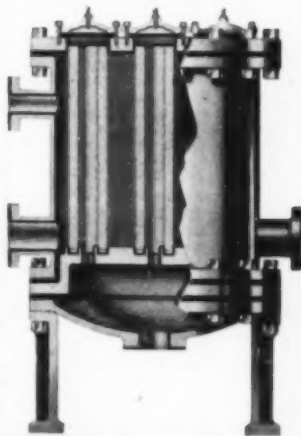
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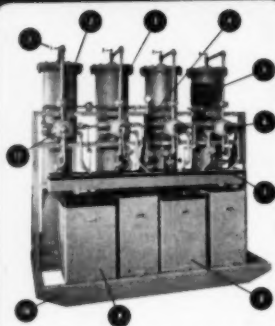
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**CHEMICAL SALES**—Desired for sales promotion and market research in the chemical industry, a postgraduate, Ph.D. preferred, age 28-38. Background should include a wide acquaintance with industrial products, details of processes and with personnel in this field. Must be capable of developing new uses for chemical process-aid products for industries in the U. S. and Canada. Headquarters in California. Full background, minimum requirements and picture requested in first letter. Box 2-9.

## SITUATIONS WANTED

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**CHEMICAL ENGINEER—M.S.** Age 34. Desire responsible supervisory position. Several years oil refinery experience, which includes research pilot plant work, process supervision. Specialized in process scale up based on dynamic similitude. Box 3-9.

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**M.S.Ch.E.—27**, married, two children. Four years' petroleum refinery process development and technical service experience. Desire process engineering position with responsibilities. Eastern location preferred. Box 8-9.

**CHEMICAL ENGINEER—B.S.Ch.E.** Age 28. Married, veteran. Four years' experience in design, development and operation in a heavy chemicals organization. Prefer position in production leading to administrative duties. Box 9-9.

**CHEMICAL ENGINEER—M.S.** Four years' diversified petrochemical development experience including unit operations, chemical reactions, pilot plant design. Desire development or design. Northeast or East Coast location. Now employed South. Present salary \$6400. Box 10-9.

**CHEMICAL PROCESS ENGINEER—B.Ch.E.** Four years' experience in industry. Desire employment of a supervisory nature in process engineering. Prefer to locate in the Midwest. Box 11-9.

**CHEMICAL ENGINEER—M.S. M.I.T.** 1948. Age 31, family, veteran. Six years process engineering and production supervision in refining and in petrochemical recovery. Present salary \$7000. Located on Texas Gulf. Box 12-9.

**ADMINISTRATIVE CHEMICAL ENGINEER—Jl.** B.S.Ch.E. Selected business administrative courses. 9½ years' experience in research, development, design, supervision, personnel, organization, management consulting. Good record of solid accomplishment. Desire responsible position. Box 13-9.

**CHEMICAL ENGINEER—32.** Ten years' experience in pilot plant, process engineering, plant start-up, and supervision in organics and with super-refining adsorbents. Seek relocation in development or process engineering. Available immediately. Box 14-9.

**PROCESS ENGINEER—M.Ch.E.** 30. Eight years' diversified experience in development, design, installation of equipment in food industry. Well qualified for responsible position in development, production or research-production liaison. Box 15-9.

**CHEMICAL ENGINEER—B.Ch.E.** Age 23, married, veteran. One year experience in chemical control of phosphates and alum. Presently unemployed. Seek plant position. Desire future foreign assignment. Box 16-9.

**CHEMICAL ENGINEER - MANAGEMENT** — Cornell, 1943. Alexander Hamilton Institute. One employer since graduation. Manager research and development four years; have been credit manager, sales engineer, pilot-plant supervisor, petroleum refinery engineer, chemical operator, etc. Present salary \$11,000. Age 32, married, three children. Interested in large stable company or growing small company with incentive arrangement. Unqualified outstanding references. Box 17-9.

**CHEMICAL ENGINEER**—Three years' diversified experience, industrial and sewage filtration, supervisory capacity. Two years research and development, biochemistry and nonferrous metallurgy. Alert, capable of assuming responsibility. Married, family. Box 18-9.

## PEOPLE

(Continued from page 65)

**John W. Andersen** is now group leader in charge of the chemical engineering research section of Monsanto Chemical Co.'s central research department, St. Louis, Mo. Andersen, who joined Monsanto in 1949, received a B.S. degree in chemical engineering from the University of Wisconsin in 1944. After two years' service in the navy, he returned to the University of Wisconsin where he received a Ph.D. degree in 1949.

**Richard T. Trelfa**, previously a development engineer in the paper makers chemical department of the Hercules Powder Co., Wilmington, Del., is now with Watervliet Paper Co., Watervliet, Mich., as a technical director. Watervliet Paper Co. is a manufacturer of quality coated book and label papers.

**John Weikart** was recently appointed assistant head in the white products and fuels section of the Standard Oil Development Co., Linden, N. J. He joined the process division of the company in 1942. Mr. Weikart is a graduate of Cornell University with a B.S. degree in chemistry and an M.S. degree in chemical engineering.

**C. H. Barkeley**, chemical engineer with Shell Development Co., Emeryville, Calif., is at Oak Ridge for a year's course of study on nuclear engineering problems. Doctor Barkeley received his A.B. degree from Pomona College, and his Ph.D. from the University of California.

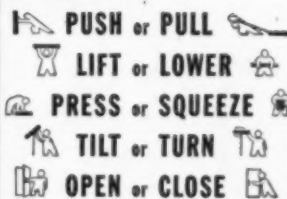
**M. H. Bigelow**, technical director of the Plaskon Division, Libbey-Owens-Ford Glass Co., Toledo, Ohio, has been named a director-at-large of the Armed Forces Chemical Association, and secretary of the Great Lakes Section, Forest Products Research Society. Since 1948 he has been serving as an Army Chemical Corps special consultant in charge of the rehabilitation of 230 German chemical plants.

(More About People and Necrology on page 68)

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Ledeon cylinders used for air, oil, water, gas or steam operation with medium, heavy or super-duty models, provide a large number of variations and adaptations to meet your specific power or motion requirements. They are available in many diameters and stroke lengths with suitable head and rod attachments to provide almost any desired mounting. Standard Ledeon cylinders and mountings from distributors' stocks in major cities. Special cylinders if required. All J.I.C.

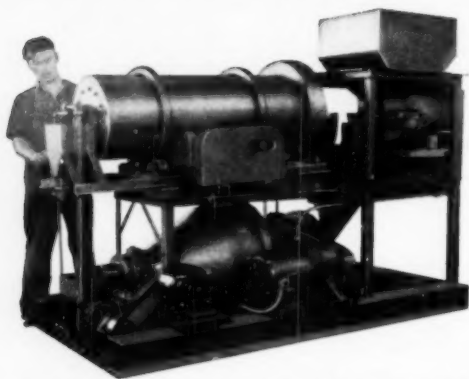
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Make power and water connections only and the Hardinge WET GRINDING UNIT is ready to perform. Self-contained and portable. 6½' high. Includes Conical Mill, Counter-Current Classifier, launders, feeder, pump and "Electric Ear" grinding control. Similar unit available for dry grinding. Write for Bulletin AH-373-40.

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LEFT: Nagle portable Combination Sump and Pump—a 1½" type SW-OB handles porcelain enameling slips and glazes from mills to overhead storage—33 g.p.m. of 1.9 specific gravity material against 50' head.



RIGHT: Nagle 2" type SW-OB, frame 95 J Hastalloy pump mounted in a Hastalloy vessel, handles sulphuric acid saturated with chlorine from a low pressure reactor. This single stage inverted entrance pump is for wet pit submerged operation. Has dual radial bearings and balanced shaft.



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PUMPS FOR ABRASIVE AND CORROSIVE APPLICATIONS

## PEOPLE

(Continued from page 67)

**John A. Scott**, manager, since its inception, of the petrochemical division of the Sinclair Oil Corp., has been named executive vice-president of the Sinclair Chemicals, Inc., newly formed subsidiary of the parent company. Mr. Scott joined the Sinclair organization in 1934 as a chemical engineer in the research and development department at East Chicago upon graduating from the University of Minnesota with a degree in chemical engineering; he later transferred to Sinclair's Corpus Christi refinery and subsequently came to New York as assistant to the vice-president in charge of research and development.

## Necrology

REUBEN S. TOUR

Reuben S. Tour, professor of chemical engineering and head of that department at the University of Cincinnati since 1921, died Aug. 1, 1952.

Early in his career he was associated with Consolidated Gas Co. and held the first chair in gas engineering at the University of California as assistant professor in gas engineering. He saw service in the U. S. Army in World War I as First Lieutenant and Captain as technical director of synthetic ammonia production in the Ordnance Department at Sheffield, Ala., and two years after his discharge went to the University of Cincinnati where he directed accredited programs in chemical engineering and metallurgical engineering. He wrote many papers on various engineering subjects.

Professor Tour was born in Troy, N. Y. He received a B.S. in chemical engineering, Michigan (1910); holder of the Michigan Gas Association fellowship (1910-1911); M.Sc.E., Michigan, 1916, and Ch.E. degree, Michigan (1926).

Professor Tour was active in the promotion, and the sponsor, of the University of Cincinnati Student Chapter of A.I.Ch.E. He served as a member of the Projects Committee of the national A.I.Ch.E. and was active in the organization and the first chairman of the Ohio Valley Section and a member of the Executive Committee of that Section since its organization in 1945.

A Resolution was adopted by the Ohio Valley Section and a copy of same sent to his family as a measure of respect and admiration.

Page 69

How Would You

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**Boiling Hydrochloric Acid?**

**THIS CONDENSER...STILL GOOD  
AFTER 2½ YEARS SERVICE  
...PROVIDES AN ANSWER**

Where processing equipment is exposed to strong corrosives, trouble and expense may often be eliminated by use of a high nickel alloy.

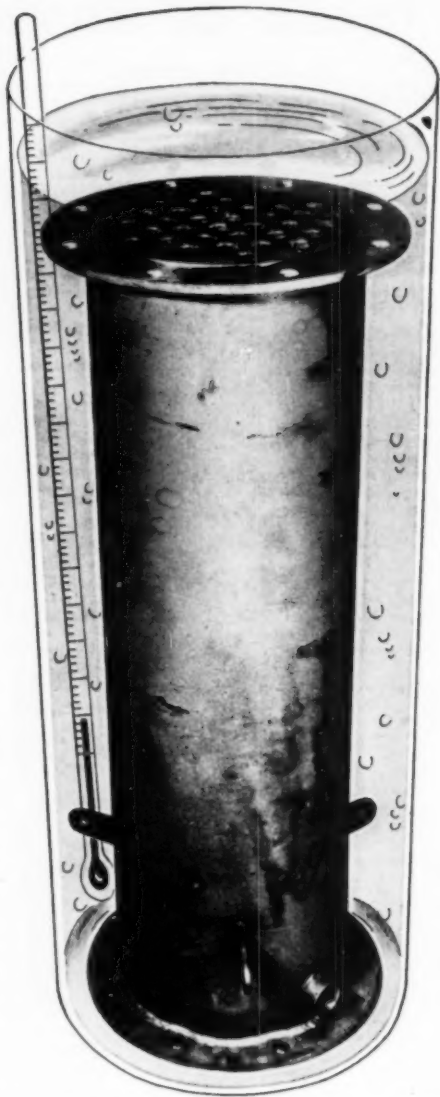
For instance, a series of nickel-base alloys trade-named "Hastelloy," produced by the Haynes Stellite Company, Kokomo, Indiana, a Division of Union Carbide and Carbon Corporation, are widely used for components exposed to corrosion from sulfuric and hydrochloric acids.

Hastelloy alloy B . . . selected for tubes and end plates of the condenser shown above . . . has given more than 2½ years of service in hydrochloric acid distillation, 2 to 3 days per week, 8 hours per day, yet shows no visible deterioration.

The fabricator, Kay Industries of Detroit, chose this high nickel alloy because it is one of the very few commercially available materials adequate to handle acid in concentrations that vary from 1 to 10%, with temperatures up to the boiling point . . . making it one of the most corrosive agents known to the chemical industry.

Hastelloy alloy or some other high nickel alloy may be the complete answer to your particular equipment or production problems. Write us, today, for counsel and data.

At present, most of the nickel produced is being diverted to defense. Through application to the appropriate authorities, nickel is obtainable for the production of engineering alloys for many end uses in defense and defense supporting industries.



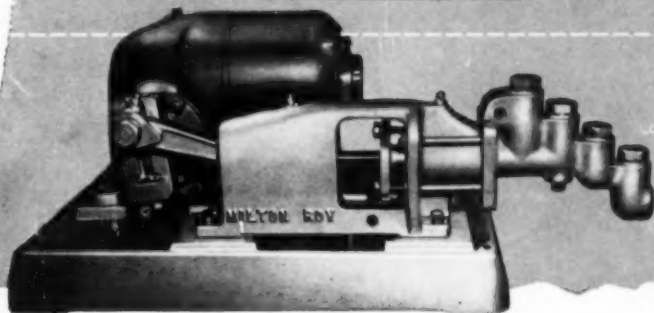
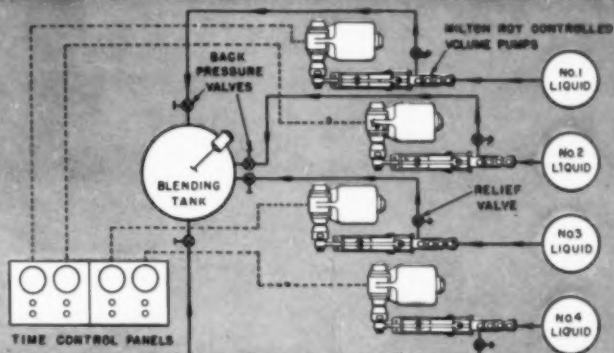
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hour each of two colors; the other two 20 gallons per hour each of the other two colors. Pressures are 15 psi.

Continuous or intermittent Milton Roy formulation and control equipment of this type effects genuine economies applied wherever precision liquid component blending is encountered. Costly variations in formulae are eliminated by holding to an accurate delivery of a fraction of one per cent for most applications. As air-powered or motor-driven units, as components of automatic systems complete with a variety of automatic controls and accessory equipment, Milton Roy Controlled Volume

Pumps give an assured accuracy and uniformity of product often impossible to obtain by any other method. Necessary changes in formulae can be accomplished quickly and accurately by a variety of controls. Capacities range from 3 milliliters per hour to about 50 gallons per minute, against pressures to 25,000 pounds per square inch. Practically any liquid—slurries, suspensions of solids, viscous or corrosive chemicals, tars, sludges—can be handled with equal, precise, efficiency.

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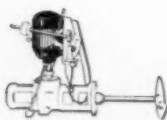
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